HERD ORGANIZATION AND MOVEMENTS OF ELK IN WIND CAVE NATIONAL PARK, SOUTH DAKOTA

Natural Resources Report
Number 13

U.S. Department of the Interior
National Park Service

Herd Organization and Movements of Elk In Wind Cave National Park, South Dakota

Kenneth L. Varland
Graduate Assistant
Iowa Cooperative Wildlife Research Unit
Iowa State University, Ames

Allan L. Lovaas
Wildlife Biologist
Wind Cave National Park
Hot Springs, South Dakota

Robert B. Dahlgren
Leader
Iowa Cooperative Wildlife Research Unit
Iowa State University, Ames

U.S. DEPARTMENT OF THE INTERIOR • NATIONAL PARK SERVICE
NATURAL RESOURCES REPORT NUMBER 13 • 1978

ABSTRACT

Herd organization, movements, and distribution of elk at Wind Cave National Park were studied from June 1973 to February 1975, to aid in management of this nonmigratory population. Thirty-two elk were marked with either ear flags, colored collars, or radio collars. Six calves were captured by hand; the remaining 26 elk were marked by immobilizing them with succinylcholine chloride shot from a dart gun (20 adult bulls in a baited corral trap, 4 adult cows and a 6-month-old female calf from a helicopter, and 1 free-ranging adult cow on the ground).

Marked elk were observed 713 times and located 113 times by telemetry. The fenced, 114 km² (44-square mile) park accommodated three relatively discrete cow–calf herds, with each herd using a distinct area of the park. The largest, about 170 elk, occupied the northwestern 20.7 km² (8 square miles) (Beaver Creek region) and did not intermingle with about 90 elk occupying 25.9 km² (10 square miles) to the east (Boland Ridge region) although their ranges overlapped slightly. About 40 elk occupying the southwestern 11.7 km² (4.5 square miles) (Gobbler Knob region) occasionally intermingled with the largest herd for brief periods in January and February 1974, and a few crossed the west fence to spend spring, summer, and early fall of 1974 in a 18.1 km² (7-square mile) area of the Black Hills National Forest. Within each herd, cow–calf groupings each changed in individual composition with time. Movements of marked bulls were variable, but most remained in the northwestern portion of the park close to the trap site. Individual bulls interchanged freely between small groups of bulls from one day to the next. From limited evidence, it seems likely that the bull population is also divided into three discrete herds.

Cows and calves used the following areas most intensively: west of Red Valley in the wooded region adjacent to Highland Creek in the southeastern portion of the park; on and east of Boland Ridge; the areas in, adjacent to, and between Sanctuary and Research Reserve prairie dog towns; and areas adjacent to and including Cold Brook Canyon in the southwestern corner of the park. Bulls were seen most often in the northern half of the park.

Elk were observed most readily during the hours closest to sunrise and sunset. They generally fed in grassland areas and bedded in wooded areas. Elk usually avoided use of steep slopes in all seasons. East- and south-facing slopes were used more than west- or north-facing slopes during most of the year.

Each herd should be managed individually to prevent an overuse of the range in any one area of the park. Information from this study was used in elk trapping operations during January 1976 and 1977. Elk numbers in the Gobbler Knob region have been declining in recent years because of hunting outside the park and it was unnecessary to trap elk from this region. Reduction quotas were set for the Boland Ridge and Beaver Creek cow–calf herds; no more than the stated quota could be taken from each herd. Although 319 elk were removed from the population in 1976 and 1977, the quota for either herd was never exceeded.

If needed in the future, suggested locations for an additional trap to capture cows and calves from the Beaver Creek and Gobbler Knob regions were discussed. Adult bulls from the Beaver Creek region can be captured by baiting them into the present trap, but additional traps would be needed to capture bulls from the Boland Ridge or Gobbler Knob regions.

INTRODUCTION

The American elk or wapiti (*Cervus elaphus*) was the most widely distributed member of the deer family when Europeans first came to this continent (Murie 1951). As settlers moved westward, this animal disappeared from most of its original range. By 1900, only small relict herds remained, largely in the Rocky Mountains and along the Pacific Coast.

Elk were native to the area now known as Wind Cave National Park (WCNP) but were virtually eliminated by market hunting before 1900 (Hipschman 1959). The park, established in 1903, is a sanctuary for many species of wildlife native to the Great Plains. Lovaas (1973a) summarized the history of elk herd reestablishment and management at WCNP, beginning in 1914 when 21 Rocky Mountain elk (*C. e. nelsoni*) were transplanted from Jackson Hole, Wyoming, to a fenced 1,683-ha (4,160-acre) game preserve within the park. A transplant of 25 additional elk from Yellowstone National Park in 1916 supplemented the population. After a time, the ever-increasing herd was reduced, primarily through shooting by park rangers, and the meat donated to Indian people. Attempts to bait or drive elk out of the park through openings in the boundary fence were ineffective in controlling population growth, and some of the elk driven out may have returned to the park.

The park was enlarged to its present 11,355 ha (28,059 acres) in 1946. During the winters of 1953–54 and 1954–55, 1,000 elk, from an estimated population of 1,100, were shot. Herd reduction by shooting was terminated after 1957 because of adverse public reaction to large-scale shooting of elk in Yellowstone National Park.

The wildlife management plan for WCNP, adopted in 1964, recommended that the population be maintained at 150–300. In the fall of 1969, the elk population was estimated at 800. Consequently, from 1969 to 1972, 657 elk were trapped and transplanted into neighboring Custer State Park and the Jicarilla Apache and Ogalala Sioux Indian reservations.

Using helicopters, the population was reduced by driving elk into the park's corral trap for bison (*Bison bison*), which was modified to accommodate elk. Information from field reconnaissance, censusing, and trapping indicated that elk concentrated in three main areas within WCNP. Susceptibility of elk to capture differed greatly among areas of the park; a helicopter could not be used successfully to drive elk over the rough terrain, heavily forested area, and long distances to a single trap near the north boundary. To maintain numbers compatible with the carrying capacity of the range, refinements in elk trapping were necessary for long-term management of this nonmigratory population. The purpose of this study, therefore, was to provide information about herd organization, distribution, and movements of WCNP elk to effect overall park-wide reductions without the excessive reduction or elimination of some population segments and insufficient reductions of others. Problems in this study were similar to those faced by Craighead et al. (1972) in Yellowstone National Park and Smuts (1974) in South Africa.

Intensive field work at the park was conducted by Varland from June 1973 through August 1974. Lovaas made periodic field trips through February 1975, and a few observations were made by various park employees from February to October 1975.

STUDY AREA

Wind Cave National Park is located in the southeastern foothills of South Dakota's Black Hills. The park is bounded on the east and south by private lands, on the west by the Black Hills National Forest, and on the north by Custer State Park (Fig. 1). WCNP lies in the transition zone between the confierous forests and grasslands of the state (Shult 1972).

The northwestern part of WCNP is largely north–south wooded ridges that are hilly to steep, except for gentle slopes in the upland valleys. The re-

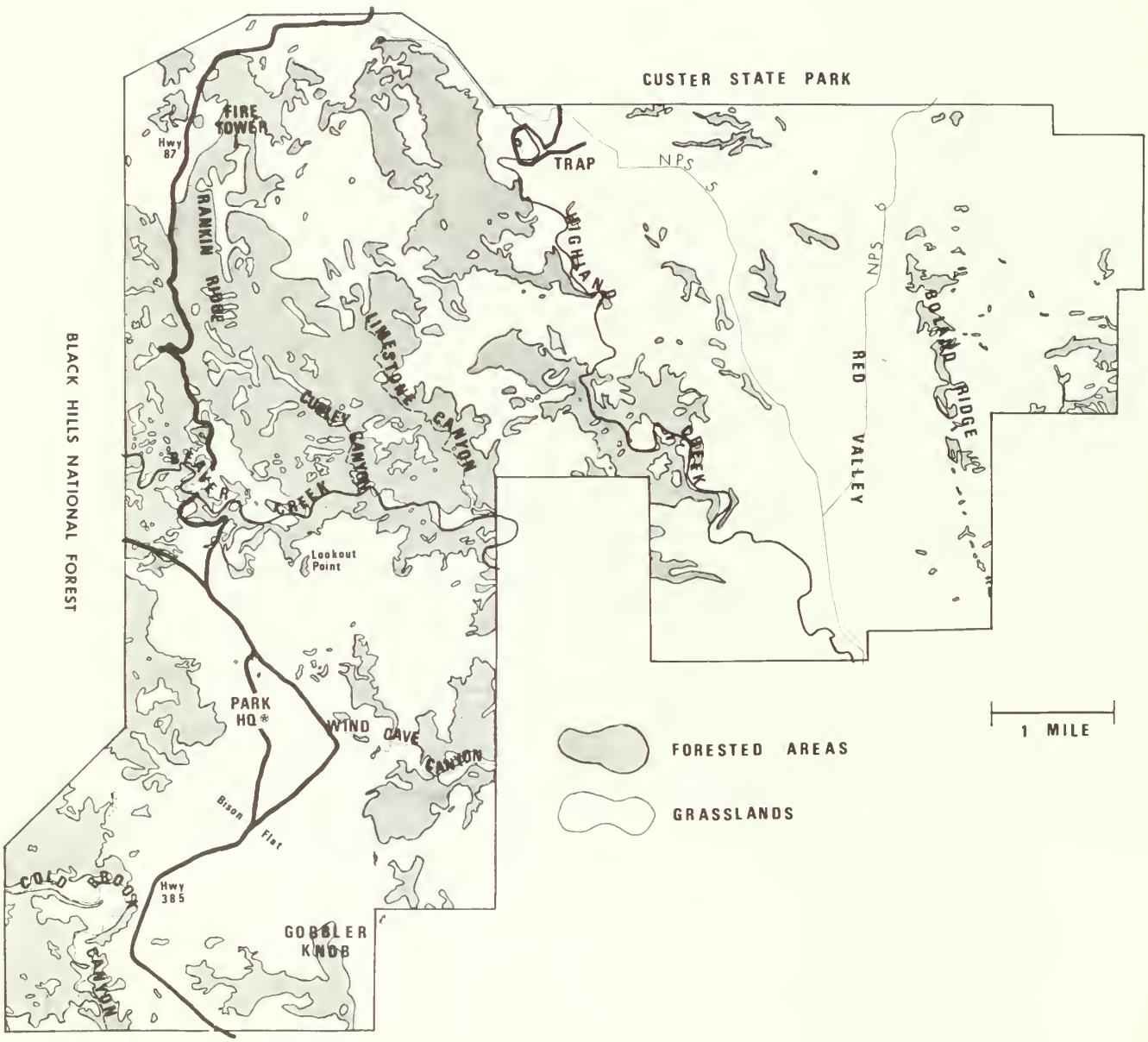

Figure 1. Map of Wind Cave National Park.

mainder of the park is in the prairie areas of the Black Hills footslopes, and major physiographic features are: (1) Red Valley, a trough-like area in the eastern portion of the park; (2) the Sandstone Hogback, a steep, angular escarpment east of Red Valley with a wooded top that is rolling to hilly and is notched by the heads of steep-walled canyons that drain to the east; and (3) the Limestone Plateau, located between Red Valley and the ridged area, which is gently sloping to hilly except for southeast flowing drainages and their tributaries, which have cut deep, wooded valleys and canyons (U.S. Soil Conservation Service 1969). Elevations range from 1,111 m (3,646 ft) msl in Red Valley to 1,528 m (5,013 ft) in the northwestern corner.

Mixed grass prairie covers about three-fourths of WCNP (Fig. 1), and the predominant grasses include western wheatgrass (*Agropyron smithii*), needlegrasses (*Stipa* spp.), common buffalograss (*Buchloe dactyloides*), bluestems (*Andropogon* spp.), bluegrasses (*Poa* spp.), grama grasses (*Bouteloua* spp.), and Japanese brome (*Bromus japonicus*). Common forbs of the park include fringed and cudweed sagewort (*Artemisia frigida* and *A. ludoviciana*), slimflower and silverleaf scurfpea (*Psoralea tenuiflora* and *P. argophylla*), upright prairieconeflower (*Ratibida columnaris*), purple prairieclover (*Petalostemon purpureum*), American vetch (*Vicia americana*), dotted gayfeather (*Liatris punctata*), sedges (*Carex* spp.), blacksamson echinacea (*Echinacea angustifolia*), hairy goldenaster (*Chrysopsis villosa*), and heath aster (*Aster ericoides*). The major browse species of WCNP is true mountainmahogany (*Cercocarpus montanus*) but other shrubs found in the park include skunkbush sumac (*Rhus trilobata*), rose (*Rosa* spp.), leadplant amorpha (*Amorpha canescens*), western snowberry (*Symphoricarpos occidentalis*), currant (*Ribes* spp.), common chokecherry (*Prunus virginiana*), and American plum (*P. americana*).

The remainder of the park is covered by ponderosa pine (*Pinus ponderosa*) found primarily in the northwestern portion. Much of the pine cover is in a savannah-like configuration, whereas some north-facing slopes have highly concentrated stands of young trees.

A detailed description of predominant range sites and vegetation was given in a conservation plan prepared for the park by the U.S. Soil Conservation Service (1969) and summarized by Lovaas and Bromley (1972). Plant names are from Beetle (1970), except that we preferred cudweed sagewort over Louisiana sagewort.

Average annual precipitation is about 46 cm (18 inches), nearly 70% of which falls between 1 May and 30 September. Snow cover is usually light and intermittent.

The park is surrounded by a 244-cm (8-ft) woven wire fence, except for a 4.8-km (3-mile) segment of 122-cm (4-ft) fence along the western boundary that permits egress of elk to national forest lands. The only interior fences are those that surround the park's headquarters and campground; thus the elk can move freely throughout the park. Two creeks flow into WCNP, Highland Creek from the north and Beaver Creek from the west; both go underground within the park boundaries (Fig. 1). Spring-fed concrete dish tanks and reservoirs are located at various places in the park to provide additional water for wildlife. The road network includes two highways, four improved dirt roads, and 26 active jeep and (or) hiking trails (Fig. 2).

Blacktail prairie dog (*Cynomys ludovicianus*) towns (Fig. 3) occupied nearly 445 ha (1,100 acres) of prairie area in 1971 (Lovaas 1973b; Petersburg 1973). Lovaas (1973b) reported that these prairie dog towns have been expanding rapidly since 1955. WCNP is a sanctuary for several other species of wildlife, including the following herbivores: bison, pronghorn antelope (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*).

MATERIALS AND METHODS

The principal technique used to determine elk herd organization and movements in Wind Cave National Park was that of observing movements of marked individuals; however, all observations of elk were recorded to determine the most heavily used ranges of WCNP.

The emphasis of the study was on the capture and marking of elk from cow–calf groups because those animals constituted the largest proportion of elk captured and removed in the park's helicopter-trapping program and because they were also sources of new calf crops. However, information concerning adult bull movements is also valuable, and attempts were made to mark those elk as well.

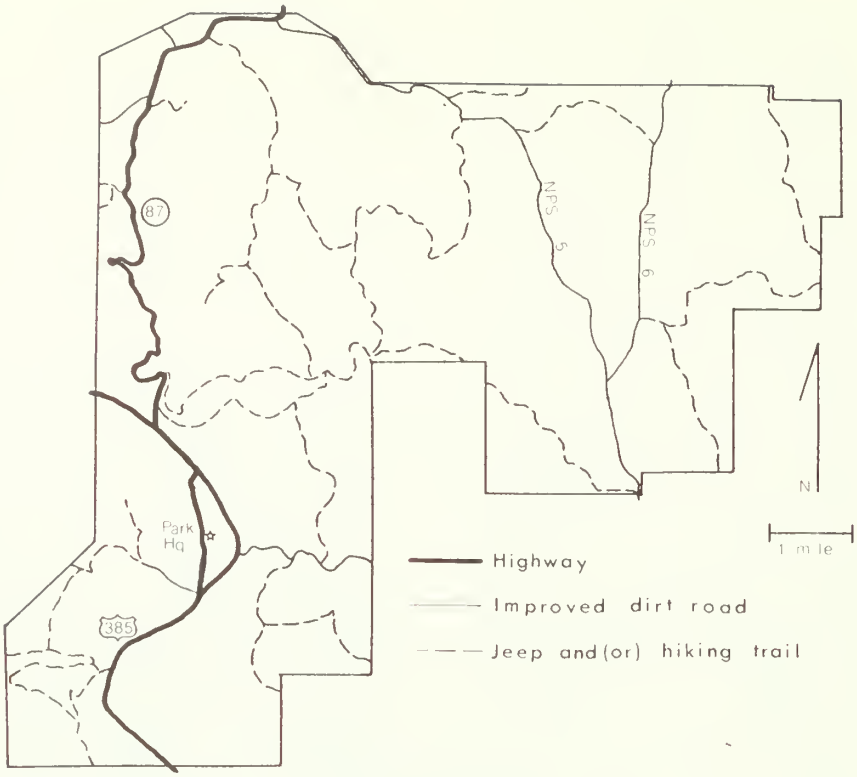

Figure 2. Network of roads and trails in Wind Cave National Park.

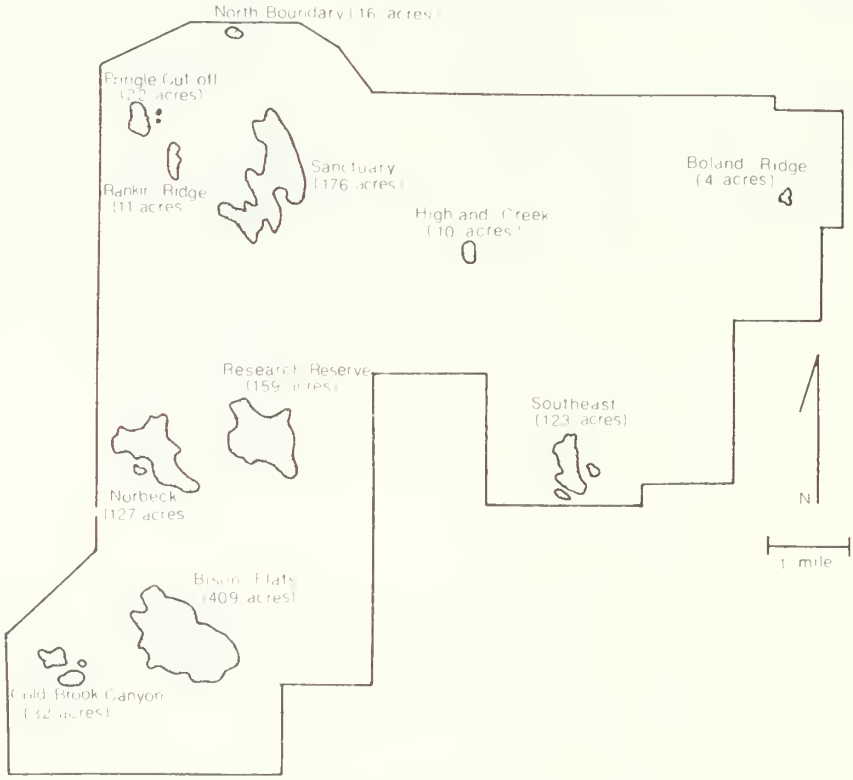

Figure 3. Prairie dog towns in Wind Cave National Park in 1971 (Lovaas 1973b; Petersburg 1973).

Elk Observations

Initially, the park was divided into three general regions (Fig. 4) which in the past had winter elk concentrations. These were the Gobbler Knob region, including Wind Cave Canyon and all areas south of the forested region just west and northwest of the park headquarters; the Beaver Creek region, including most of the area north of Beaver Creek and west of Highland Creek in the northern half of the park plus the area about 1 mile south and paralleling Beaver Creek; and the Boland Ridge region, including all areas east of Highland Creek and the adjacent forested areas west of Highland Creek in the central and southeastern portion of the park.

Generally, observations of elk were made from a motor vehicle or on foot during early morning and later afternoon hours by using either a 15–60 × spotting scope or 7 × 35 binoculars for visual relocations of marked elk; a radio receiver was used to locate radio-equipped animals. Radiotelemetry locations were made by triangulation as described by Heezen and Tester (1967).

With the aid of a U.S. Geological Survey map of WCNP (scale 1:24,000), locations of elk were recorded to the nearest 16.2 ha (40 acres) by using a six-digit code. The first two digits represented the range and township, the third and fourth, the section number, and the final two, the coordinates for the location of elk within a section. A clear-acetate-grid overlay dividing a section into 16 numbered portions of 16.2 ha (40 acres) each was used to record elk observations on the map.

The park's two highways, four improved dirt roads, and 26 active jeep and (or) hiking trails were traveled in attempts to cover the regions where elk generally were concentrated. Four hundred and five different observation routes were taken, including off-the-road hikes. The areas of the park observed from each route were delineated and divided into 16.2-ha (40-acre) tracts. No systematic pattern of routes was used; however, all portions of the park were visited regularly. Russo (1964) pointed out advantages of not using a systematic pattern of established routes for counting deer in Arizona. Dusek (1975) also used this technique of regular but nonsystematic visits for studying competition between deer and cattle on ranges in Montana.

Information recorded for each field trip included observation route taken as well as the following data

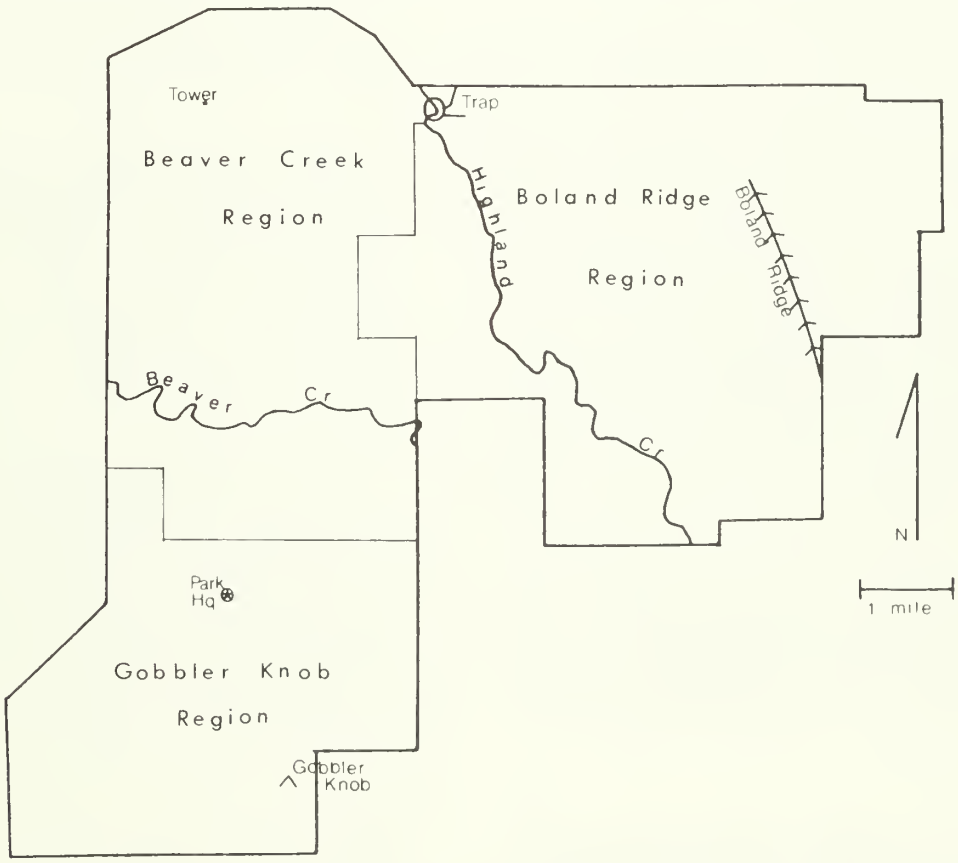

Figure 4. The three general regions of Wind Cave National Park.

for each elk group observed: time, location, activity, group size, sex, age, vegetation type, degree of slope, and slope exposure.

Groups of elk were classified as either bull groups or cow–calf groups. Bull groups consisted of adult males only. Cow–calf groups included adult females, yearling females, calves, and yearling males. Adult bulls seen with cows and calves were excluded in determining sizes of cow–calf groups. Yearling males were included in the cow–calf category because 79% of all yearling males observed were with cows and calves.

Seasons corresponded with general climatic conditions: spring—March, April, and May; summer—June, July, and August; fall—September, October, and November; and winter—December, January, and February. Data for the same seasons of different years were combined.

Vegetation types were classified as forest or grasslands. Degree of slope was estimated as level to gentle (0–25°) or medium to steep (>25°). Slope exposures were classified according to the four cardinal points (N, S, E, W) or as level ground (having little or no slope).

To determine which general areas of WCNP were used most heavily by elk, we divided the park into quarter-sections (64.7 ha or 160 acres). We summed the numbers of marked and unmarked elk seen in each quarter-section, and then divided that sum by the total number of trips to each 16.2-ha (40-acre) tract within each quarter-section to obtain an average number of elk per trip to each quarter-section. The number of observation trips to each tract was recorded (an observation trip means only that a tract was visible from a route and does not mean that we necessarily traveled through it). The average numbers of elk per 100 trips for the quarter-sections were arrayed and mapped to show areas of primary and secondary use. If the number of elk seen in a quarter-section was equal to or above the midpoint of the array, that quarter-section was designated primary range; if the number was below the midpoint, that quarter-section was designated secondary range. Separate designations were made for each season and each type of elk group. Elk were more difficult to observe in forested than in other areas and thus were perhaps underrepresented. Hikes through forested regions were made regularly to help alleviate this problem.

Capture of Elk

Searches for newborn calves were made in early morning and late afternoon almost daily during the calving seasons of 1973 and 1974. The calving season in WCNP is believed to extend from the last week in May through the third week in June. Johnson (1951) reported a calving period of 21 May to 12 June, with the peak on 1 June, for the Gallatin herd in southwestern Montana. Late calving was suspected in Montana when two calves, which were much smaller than others, were observed in mid-July. Schwartz and Mitchell (1945) reported a calving period of 15 May to 15 June, with a peak from 1 to 10 June, for Roosevelt elk in Washington. They recorded a birth as late as 10 July.

Calves were secretive during most of the summer and were not seen as often as older elk. No so-called calving grounds (Brazda 1953) were found in the park, although more calves were seen in certain areas than in others (Fig. 5).

An average of one calf per 4.2 hours was seen during the estimated 138 man-hours spent in ground searches for calves from 9 to 29 June 1973. One male and two females were captured (one female escaped before being marked) for an average of one capture per 46 man-hours.

From 27 May to 28 June 1974, an estimated 279 man-hours was spent in ground searches, with an average of one calf observed per 3.9 man-hours. Ground searches in 1974 resulted in the capture of two females and one calf where the sex was not determined. An average of 93 man-hours was spent for the capture of each calf.

Most calves chased on foot escaped easily because they could outrun pursuers. Two calves were captured as a result of chases during ground searches; both went into the prone position after being chased a short distance. The remaining calves stayed in the prone position from the time they were first sighted until the time of capture. Bedded calves generally became frightened and ran away when a searcher inadvertently walked close by. One of those that remained down was captured.

In 1974, early morning searches for calves were made with a helicopter. Nursery groups were located from the air, and attempts were made to split individual calves away from the group and then force the frightened calf into the prone position. When this occurred, the passenger disembarked, and the helicopter hovered over the calf until the capture was made.

Forty calves were seen during 5 hours spent in helicopter searches from 19 to 21 June 1974; an average of 8 per hour. Only one male was captured. More calves may have been captured if the helicopter had been used earlier in the month when calves were younger.

Older elk were captured by immobilizing them with succinylcholine chloride shot from a dart gun on the ground, from a helicopter, or in a corral trap.

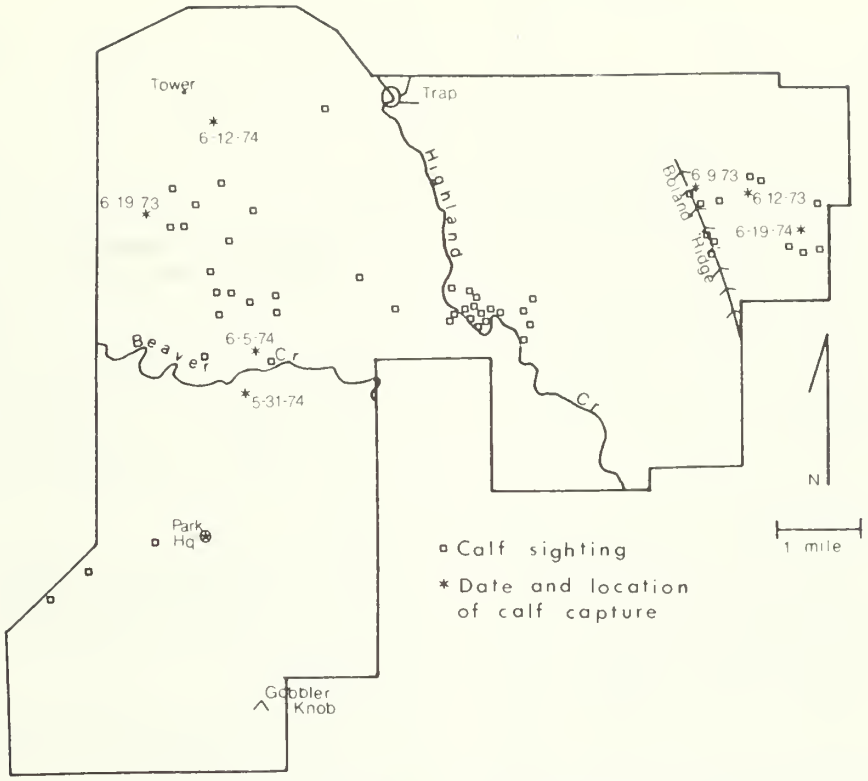

Figure 5. Locations of elk calves sighted or captured from 9 to 29 June 1973 and from 27 May to 28 June 1974 at Wind Cave National Park.

The least successful ground-capture method used was the driving of elk by hunters on foot; only an adult cow and a yearling bull were hit by a dart with this method (Varland 1976b). Stalking was the most successful, with hits on five adult cows and one adult bull. Two adult and two yearling bulls were hit from natural blinds (large rocks, trees, etc.). Elk that escaped into rough, wooded areas after they were hit were difficult to follow or find. Only one cow was marked successfully by using a ground immobilization method (stalking). Although ground methods were relatively ineffective, a large number of observations was made of both marked and unmarked elk during those activities, thus the time was not wasted.

Adult bulls often entered the corral trap, which was baited with salt; 23 were captured from October 1973 to January 1974, and 2 in the summer of 1974. This does not include a bull that escaped before the gate was closed and two that jumped the corral fence after being trapped.

No cows and calves were attracted to the baited trap, but cow-calf groups seldom were seen within 1.6 km of the structure. In previous years, cows and calves were captured when they wandered into the trap (Lovaas 1973a), thus cows and calves may have been captured during this study if traps had been located within the areas they used.

Not counting original construction cost, the corral method was the least costly technique used to capture and mark elk ($24.75 per elk). Use of a helicopter was more effective and less expensive ($280.20 per elk) than blind, drives, or stalking ($2,454.00 per elk) for immobilization of free-ranging elk (Varland 1976b). Costs include salaries, vehicle and helicopter expenses where applicable, and costs for immobilization equipment (does not include the cost of drugs and marking devices).

Marking of Elk

Thirty-two elk were marked during the study: 20 bulls, 5 cows, 6 newborn calves, and a 6-month old female calf. Belt collars were placed on 9 bulls, and rope collars on 10 bulls and 1 cow. One bull, 4 cows, and the 6-month- old calf were equipped with radio collars. Only ear flags were attached to newborn calves.

Marked elk were assigned an individual code number to denote where and when an elk was marked (BR=Boland Ridge, BC=Beaver Creek, GK=Gobbler Knob, and CT=corral trap). For example,

elk BR3 was the third elk captured and marked in the Boland Ridge region.

Colored ear flags (3.75×46 cm or 1.5×18 inches), used to mark individual calves, were constructed from Saflag material (Safety Flag Company of America, Pawtucket, R.I.). Metal ear tags were inserted through slits in the folded Saflag, and the entire marking device was then attached to the calf's ear with ear-tag pliers. One flag was attached to each ear.

Older elk were marked with collars ranging from 78.7 to 83.8 cm (31 to 33 inches) in circumference (Knight 1966), depending on sex and age. Adult bulls were fitted with either a belt collar, a rope collar, or a radio collar. Cows were equipped with either a radio collar or a rope collar.

Colored belt collars were made by sewing Saflag material onto 3-ply rubberized belting 5 cm (2 inches) wide (Electrical Engineering and Equipment Company, Des Moines, Iowa), in designs similar to those described by Progulske (1957). The ends of the collar were joined together with size 25E alligator steel-belt lacing (Electrical Engineering and Equipment Company) into which a 10-penny nail was placed and bent over.

Rope-type collars similar to those used by Craighead et al. (1969) were made by inserting six pieces of colored Saflag (7.6×22.9 cm or 3×9 inches) through half-inch polypropylene rope at 10.2-cm (4-inch) intervals in color combinations that enabled us to recognize individuals at sight from either side. The two ends of the rope collar were joined by using four No. 3 hog rings.

Six radio-transmitter collars (150–151 MHz) were purchased from Wildlife Materials, Inc., Carbondale, Ill. Visual recognition of three radio-equipped elk was made possible by either sewing Saflag strips (3.75 cm or 1.5 inches wide) to the collars, or by wrapping colored tape (Scotch brand colored cellophane, No. 650, Minnesota Mining and Manufacturing Co., St. Paul, Minn.) around them at 10.2-cm (4-inch) intervals. Three collars were marked with Saflag and three with colored tape. The ends of each collar were joined by using belt lacing and a nail.

Visibility of collars was good throughout the study. Saflag was more durable and more visible than the colored tape on radio collars. Bulls with collars were not individually recognized in 18% of the sightings because of poor light, long distances, or rising heat waves. Rope collars were more readily recognized than belt collars. The maximum distance at which a collar was individually recognized through a 15–60 × spotting scope was approximately 3.2 km (2 miles) for a rope collar and 2 km (1.25 miles) for a belt collar. Optimum conditions were necessary for recognition of collars at distances greater than 0.8 km (0.5 mile). Collars generally were recognizable under relatively poor conditions at distances of 0.4 km (0.25 mile) or less. Two belt collars (white with yellow stripes and white with yellow dots) were sometimes difficult to differentiate.

One belt collar (blue with green dots), recovered from an adult bull found dead (probably poached) about 17.5 months after it was marked, was worn but still recognizable at 0.8 km (0.5 mile), through a 20 × spotting scope.

The longest periods that collars were known to be recognizable on a living elk were 451 days for a rope collar and 438 days for a belt collar. However, we do not know how long the collars would retain a recognizable pattern.

Ear flags could be seen with the naked eye at distances up to 0.8 km (0.5 mile). Ear flags on certain individuals were recognizable up to 1.6 km (1.0 mile) when using a spotting scope.

Ear flags were fairly durable, but some were eventually lost. The two calves marked in 1973 retained both flags until late November 1974, when each lost one. One of the calves marked in 1974 was never relocated, one lost an ear flag after about 1 month, one after about 5 months, and one retained both up to the end of field work. One ear tag and the attached flag (elk BC4) was sloughed about 1 month after the calf was marked and was found later in the summer in good condition, with ear cartilage still inside the tag.

The known transmitting life for radio collars ranged from 27 to 351 days, with a mean life of 186 days. This does not include one radioed cow that was never relocated either visually or by radio telemetry after it was marked; this cow's radio had been activated 39 days before it was attached to the cow and was working properly at the time of attachment. One radio transmitted properly for the first 83 days after activation, then stopped for at least 184 days, and then transmitted again for 46 days before it stopped permanently (perhaps because of battery failure).

Cow–Calf Herds

Areas used by cows and calves were determined by mapping all observations of individuals marked in a particular region of the park and then connecting the outermost points (Fig. 6). The cow–calf population was divided into three relatively discrete herds. Elk of the Boland Ridge region occupied an area of 25.9 km² (10 square miles) in the eastern portion of WCNP. Beaver Creek elk occupied about 20.7 km² (8 square miles) in the park's northwestern corner. Gobbler Knob elk spent most of their time during winter in a 11.7-km² (4.5-square-mile) area in the park's southwestern corner. The area in the park occupied by the two elk marked in this region varied from 23.3 to 28.5 km² (9 to 11 square miles), depending on whether one includes brief winter movements to the Beaver Creek region and other areas in the Gobbler Knob region. Gobbler Knob elk occupied an additional area of about 18 km² (7 square miles) in the Black Hills National Forest west of the park from early April to early October 1974.

Cow–calf groups were largest during winter months, and group size was highly variable (Table 1). During ground counts in the winter of 1973–74, the largest group seen, 140, was in the Beaver Creek region, and groups ranging from 51 to 120 were observed there frequently. The largest group seen in the Boland Ridge region was 80 elk, and groups ranging from 40 to 70 were seen commonly. Groups of from 20 to 46 were seen frequently in the Gobbler Knob region.

The same trend in group size was observed for the winter of 1974–75, with the largest groups in the Beaver Creek region and smaller groups in the Boland Ridge and Gobbler Knob regions. The largest groups observed in the Beaver Creek, Boland Ridge, and Gobbler Knob regions were 162, 91, and 41, respectively. Elk marked in a particular region usually were seen associated with the larger groups of that region. Calf production probably accounted for the increased group sizes from one winter to the next within a particular region, except in the Gobbler Knob region where elk numbers decreased. The probable reason for the decline of elk in the Gobbler Knob region, hunting outside the park, will be discussed later. The mean ratio of calves per 100 cows in the park during July, August,

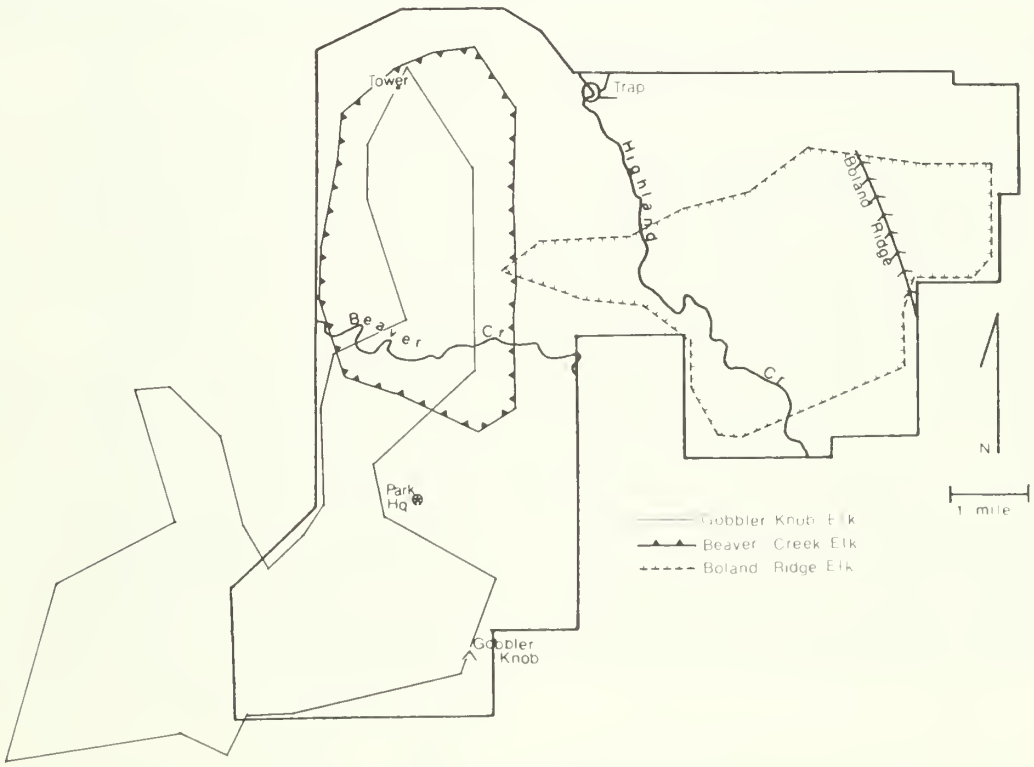

Figure 6. Areas used by all cows and calves marked in each region in Wind Cave National Park.

Table 1. Cow–calf groups and bull groups seen during the four seasons at Wind Cave National Park.

Season	Total elk	No. of groups	Mean size ± SD	Range
		Cow–calf groups		
Spring	2,937	195	15.1 ± 20.7	1–99
Summer	3,423	311	11.0 ± 17.3	1–127
Fall	4,874	213	22.9 ± 31.3	1–119
Winter	6,802	162	42.0 ± 48.5	1–162
Year-long	18,036	881	20.5 ± 29.4	1–162
		Bull groups		
Spring	1,272	279	4.6 ± 4.5	1–17
Summer	2,146	523	4.1 ± 5.1	1–35
Fall	1,493	482	3.1 ± 3.4	1–30
Winter	1,543	331	4.7 ± 5.0	1–33
Year-long	6,454	1,615	4.0 ± 4.5	1–35
Overall	24,490	2,496	9.8 ± 17.8	1–162

and September 1973 was 34:100. The ratio in the Beaver Creek region was 29:100 and in the Boland Ridge region was 49:100. Too few cows and calves were seen in the Gobbler Knob region during this period in either year to calculate a meaningful ratio. In 1974, the mean ratio for WCNP was somewhat higher (43:100) than the previous year, and ratios in the Beaver Creek region (40:100) and the Boland Ridge region (46:100) were comparable.

An aerial elk census was conducted on 13 March 1975. One hundred and twenty-four bulls were observed throughout the park. Only four groups of cows and calves were seen (Lovaas 1975), including a group of 36 in the Gobbler Knob region and one of 170 in the Beaver Creek region. These group counts were similar to ground counts made in the winter of 1974–75 in those regions. Two groups of cows and calves were seen about 1.6 km (1 mile) apart within the Boland Ridge region, one of 7 and one of at least 28. There could have been more in the second group because it was scattered through a wooded area. Lovaas et al. (1966) reported that counts of elk were most accurate when there was snow cover and elk were in the open, away from wooded areas. Therefore, we believe some of the elk in the Boland Ridge region were not seen during the aerial census; this explains the discrepancy between the ground and aerial counts.

Bull Herds

From limited evidence, it seems likely that the bull population was also divided into three discrete herds. The areas occupied by these herds differed slightly from those occupied by cow–calf herds, particularly in the area south and east of the corral trap.

Bulls marked in the trap interchanged freely between bull groups from one day to the next throughout the study, although they generally remained in the northwestern portion of the park (Beaver Creek region); only a few moved to other regions at various times. All sightings of 15 of the 20 marked bulls were within a 6.4-km (4-mile) radius of the trap, and only two were seen more than 9.7-km (6 miles) from the site. We inferred that the Boland Ridge and Gobbler Knob regions each had separate bull herds also because (1) unmarked bulls were seen consistently in those regions, several of which were identifiable by antler conformation and condition (broken tines, etc.); (2) marked bulls were rarely seen in either region throughout the study; and (3) no marked bulls were ever seen in either region during the rut. It should be noted, however, that cows from the Gobbler Knob region spent a large portion of the rutting period outside the park, and some of them may have mated with bulls that lived outside the park.

Bulls marked in the trap were relocated a total of 321 times. Dispersal from the trap site was varied. Spring sightings (116) were concentrated south and west of the trap (Fig. 7). Long-range movements included one bull seen east of Boland Ridge near the park's eastern boundary and another bull that crossed the park's boundary fence into the Black Hills National Forest.

Summer sightings (84) generally were located west of the trap, with another concentration occurring southwest of the park's fire tower (Fig. 8). A few scattered sightings were made southeast of the trap, including one bull seen on Boland Ridge (the same bull seen there in the spring, Fig. 7). Only one marked invididual was seen south of Beaver Creek during this season.

Fall sightings (46) usually were scattered west and south of the trap site. Movements during this period may have been related to the rut, because a large cow–calf herd was in the Beaver Creek region (elk CT6 was seen with a harem in this region in September 1974). Marked bulls were seldom seen east or southeast of the trap during fall (Fig. 9). One bull sighted in the Black Hills National Forest during spring (Fig. 7) was killed in the fall by a hunter about 3.2 km (2 miles) north of where it first was seen outside the park. Another bull was seen as far away as the park's southwestern corner (Gobbler Knob region) in November 1974.

Winter locations (75) were similar to those during fall, except that more sightings were made east and

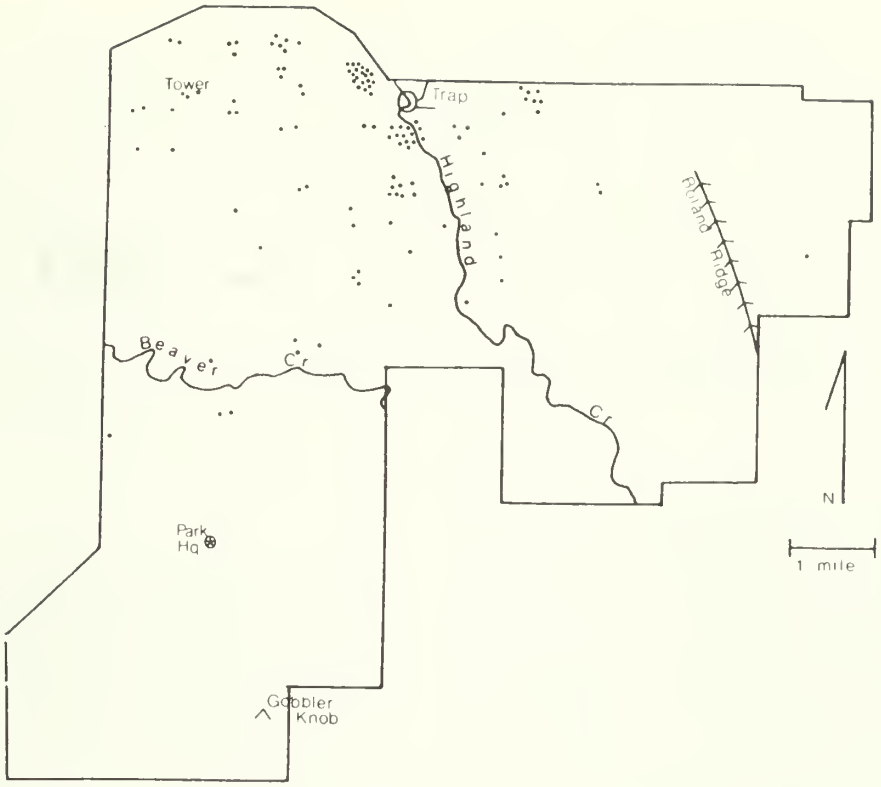

Figure 7. Locations of marked adult bulls during spring 1974 and 1975.

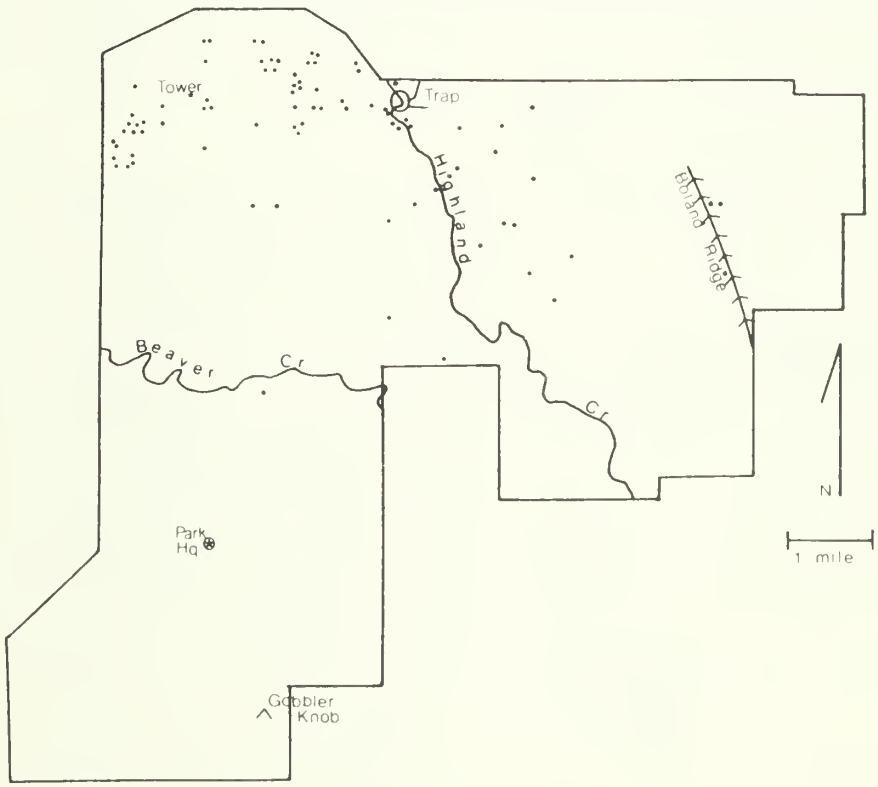

Figure 8. Locations of marked adult bulls during summer 1974.

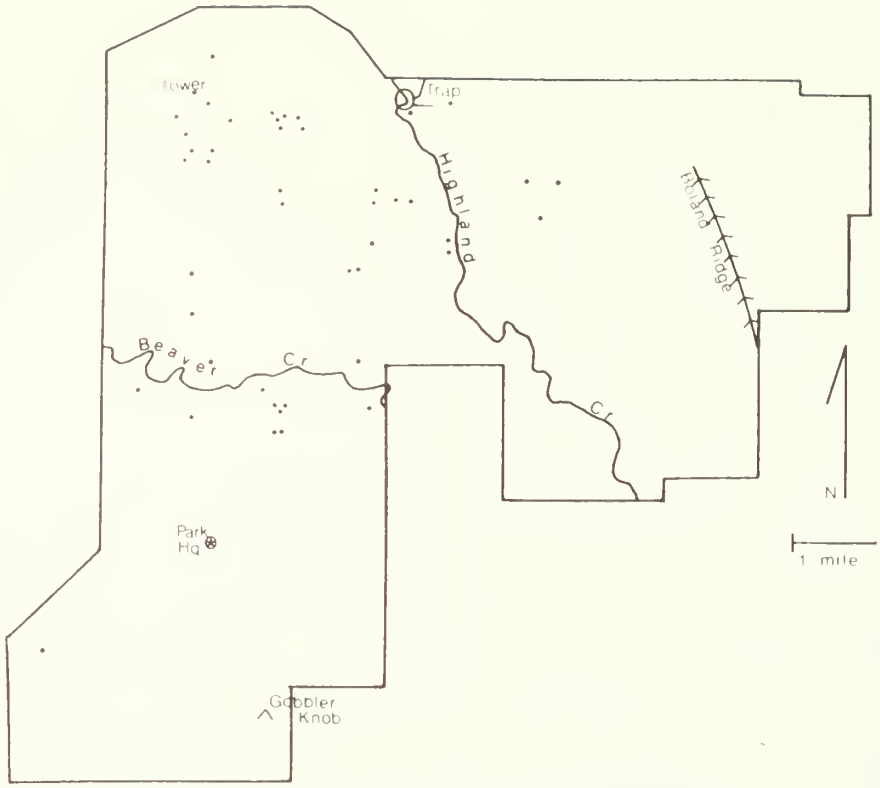

Figure 9. Locations of marked adult bulls during fall 1973 and 1974.

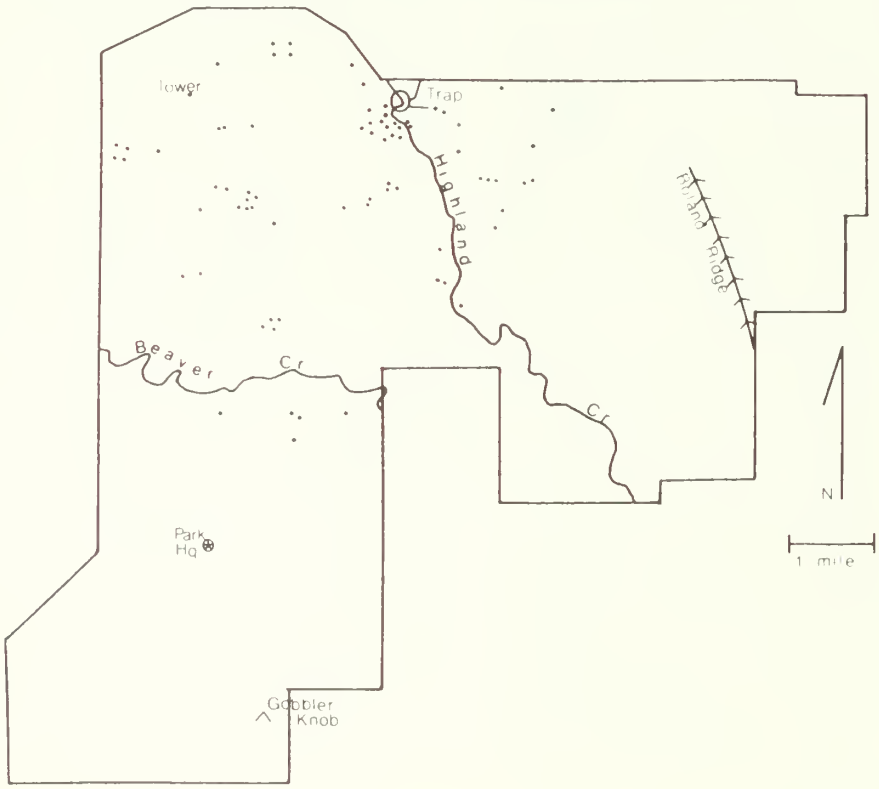

Figure 10. Locations of marked adult bulls during winter 1973–74 and 1974–75.

southeast of the trap (Fig. 10). Marked bulls were not observed to make long-range movements to other regions of the park during winter.

Mean sizes of bull groups varied less by season than did cow–calf groups, but were highly variable within seasons (Table 1). Mean group size was highest in winter, but the largest group (35) was seen during summer. Few bulls were observed in the Gobbler Knob region, and groups there never exceeded 10 animals. Group-size characteristics for bulls of the Beaver Creek and Boland Ridge regions were similar; small groups of 2–10 bulls were seen most often, followed by single bulls, and then by groups of 11–20. Occasionally, groups of 31–40 bulls were seen in both regions.

Movements and Interactions of Marked Individuals

Relocations of marked individuals generally confirmed the presence of separate herds of elk. Of the 32 elk captured and marked in the park, only two were never relocated. Eight hundred and twenty-six relocations were made of 30 elk (321 locations of bulls marked in the corral trap and 505 of elk marked elsewhere), including 713 made visually and 113 solely by radio telemetry. Radio-equipped elk sometimes were located visually after a telemetry location was made. The following discussion concerns individual movements of marked cows and calves. Locations of individual bulls were given by Varland (1976a).

Boland Ridge Region

Two cows and two calves were marked in the Boland Ridge region, but one cow (BR4) was never relocated. Elk BR1, BR2, and BR3 stayed in the eastern half of the park and were associated with the herd there that numbered 80 elk in 1973 and 91 in 1974. Marked elk generally were found in two areas: (1) on or east of Boland Ridge, and (2) west of Red Valley in the wooded region adjacent to Highland Creek in the southwestern portion of the Boland Ridge region. Cow–calf groups were seldom seen in Red Valley, a prairie area with only small patches of wooded cover. Movements of the three marked elk were similar to each other. No major seasonal shifts in movement patterns were noted, except that few relocations were made west of Red Valley during fall. Elk marked in this region were never seen with cows or calves marked in other regions of the park, but commonly were seen together. All three marked elk were seen together seven times, and on 19 occasions two of the marked elk were seen together, exclusive of other marked elk. Elk BR1 and BR2 were seen together nine times, BR1 and BR3 were seen together eight times, and BR2 and BR3 were seen together twice.

Elk BR1, a spike bull marked as a calf on 12 June 1973, east of Boland Ridge, was relocated 57 times (Fig. 11). This elk was last seen on 7 February 1975.

Elk BR2 was marked as an adult cow on 3 January 1975, on the west slope of Boland Ridge and was relocated 36 times (Fig. 12). This cow's radio transmitter did not work most of the time, and visual observations were made in most instances. This cow was last located on 24 January 1975.

Elk BR3, a male calf captured with the aid of a helicopter on 19 June 1974, east of Boland Ridge, was relocated 26 times and was last seen on 28 February 1975 (Fig. 13).

Beaver Creek Region

Two cows and four calves were marked in the Beaver Creek region. Elk BC6, a female calf, was never relocated after being marked. The remaining five marked elk stayed in or near and ranged throughout the wooded northwestern portion of the park. These elk were associated with a cow–calf herd that numbered 140 elk in 1973 and 170 in 1974. Movements of the marked animals were similar to each other. No major seasonal shifts in movements occurred, although few relocations during summer and fall were made north of a line extending from the fire lookout tower to the corral trap. Elk marked in the Beaver Creek region were associated in different combinations on 45 occasions during the study (Table 2). Elk BC4 and BC5 were marked late in the study but frequently were seen associated with three elk marked earlier. Individuals marked early in the study commonly were seen together at various times throughout the study. The five elk were never seen together at the same time.

Table 2. Frequency of observed associations in various combinations involving two, three, or four of the five elk marked in the Beaver Creek region.

Associations observed	Frequency occurrence
BC1 + BC2	8
BC1 + BC3	3
BC2 + BC3	6
BC2 + BC4	2
BC2 + BC5	5
BC1 + BC2 + BC3	11
BC1 + BC2 + BC4	1
BC1 + BC2 + BC5	1
BC1 + BC3 + BC5	2
BC1 + BC4 + BC5	1
BC2 + BC3 + BC5	1
BC3 + BC4 + BC5	1
BC1 + BC2 + BC3 + BC4	1
BC1 + BC2 + BC3 + BC5	2

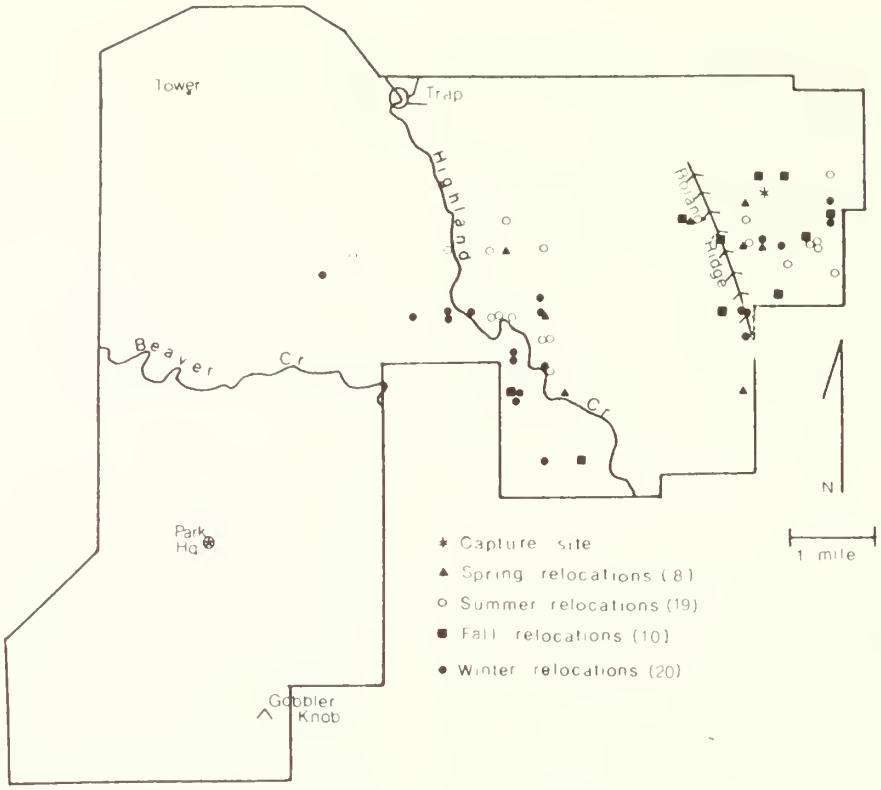

Figure 11. Locations of elk BR1 from 12 June 1973 to 7 February 1975.

The range of elk marked in this region overlapped slightly with the range used by elk marked in the Boland Ridge region. However, marked elk from the Beaver Creek region were never observed mingling with marked elk from the Boland Ridge region, nor were they seen in the Gobbler Knob region.

Elk BC1, a female marked as a calf on 19 June 1973, near Highway 87, was relocated 53 times (Fig. 14), and was last seen on 10 December 1974.

Elk BC2, an adult cow, was stalked, immobilized, and marked on 26 November 1973 and was relocated 128 times (Fig. 15). This cow, whose radio transmitter stopped working in October 1974, was last seen on 10 January 1975.

Elk BC3, an adult cow immobilized from a helicopter, was marked on 18 January 1974, about a mile southeast of the fire tower and was relocated 46 times (Fig. 16). She was last seen on 7 March 1975.

Elk BC4, a calf of undetermined sex, was marked on 31 May 1974, on the western edge of Research Reserve prairie dog town (Fig. 3). This elk was relocated eight times (Fig. 17), and was last observed on 26 September 1974.

Elk BC5, a female calf, marked in Curley Canyon on 5 June 1974, was relocated 16 times (Fig. 18). This elk was last seen on 5 October 1975.

Gobbler Knob Region

A 6-month-old female calf (GK1) and an adult cow (GK2) were immobilized and radio-collared in January 1974, in the Gobbler Knob region. The movements of both were similar. Both elk spent the first winter primarily in the southwestern corner of WCNP in association with a cow–calf herd of 46 elk. During this period these elk made brief excursions into the Beaver Creek region. From early April to early October, they were usually relocated just west of the park in the Black Hills National Forest. Elk GK1 returned to the park in early October 1974, and was relocated several times during the winter of 1974–75, in association with a herd of 41 elk. Elk GK2 was last relocated in mid-August outside the park. Both marked elk of this region were relocated together, by visual observation 15 times and by radio telemetry 17 times. Elk from the Gobbler Knob region and the Beaver Creek region were seen associated during January and February 1974, on one occasion for each of the following combinations: GK1 + GK2 + BC1 + BC2; GK1 + BC1 + BC2; and GK1 + GK2 + BC2. The following combinations were seen during the same period on two occasions: GK1 + BC2; GK2 + BC1 + BC2; and GK2 + BC1.

Elk GK1, marked as a 6-month-old female on 4 January 1974, in the extreme southwestern corner of the

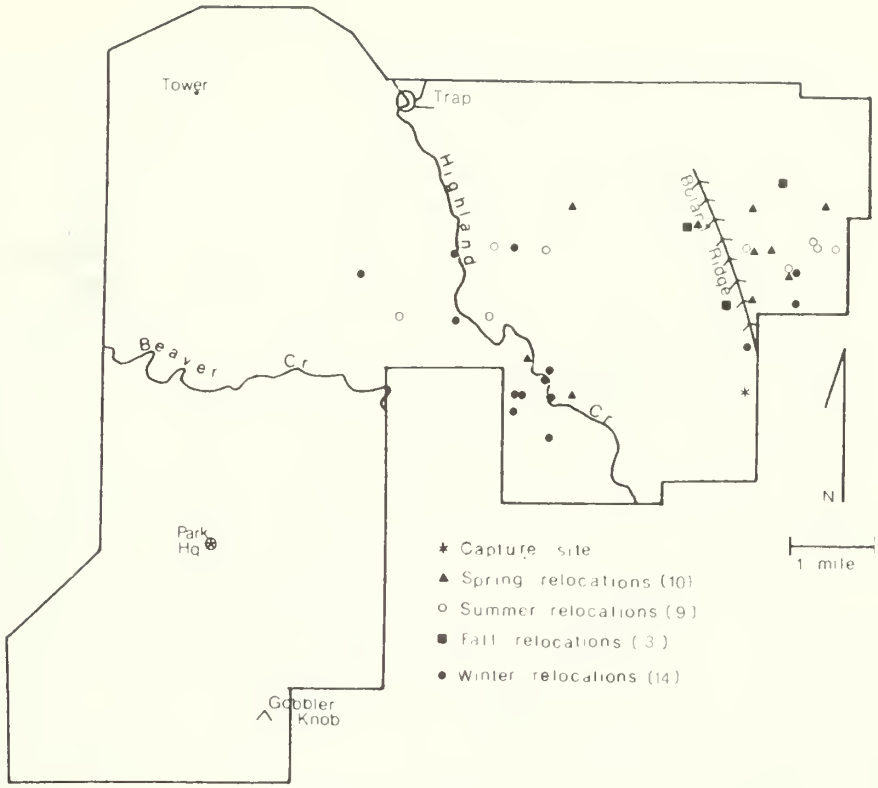

Figure 12. Locations of elk BR2 from 3 January 1974 to 24 January 1975.

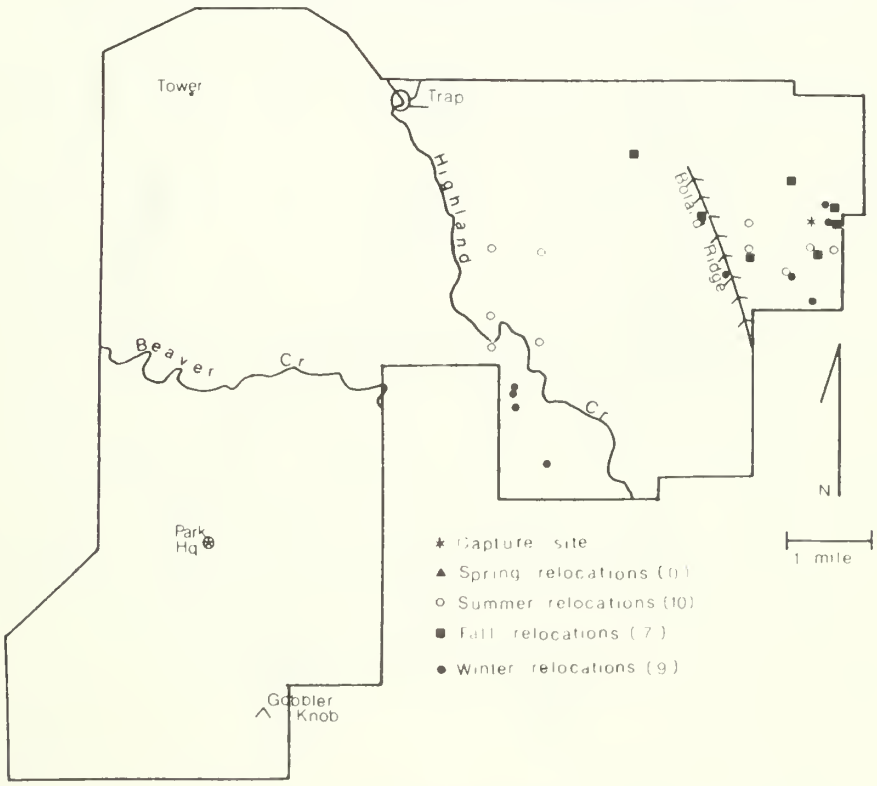

Figure 13. Locations of elk BR3 from 19 June 1974 to 28 February 1975.

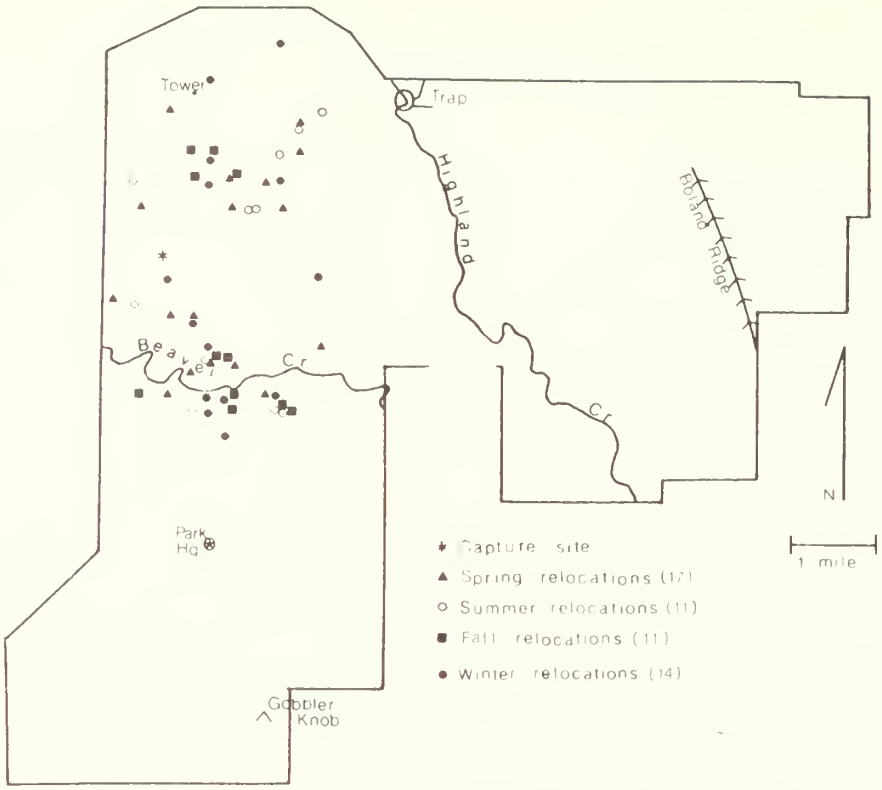

Figure 14. Locations of elk BC1 from 19 June 1973 to 10 December 1974.

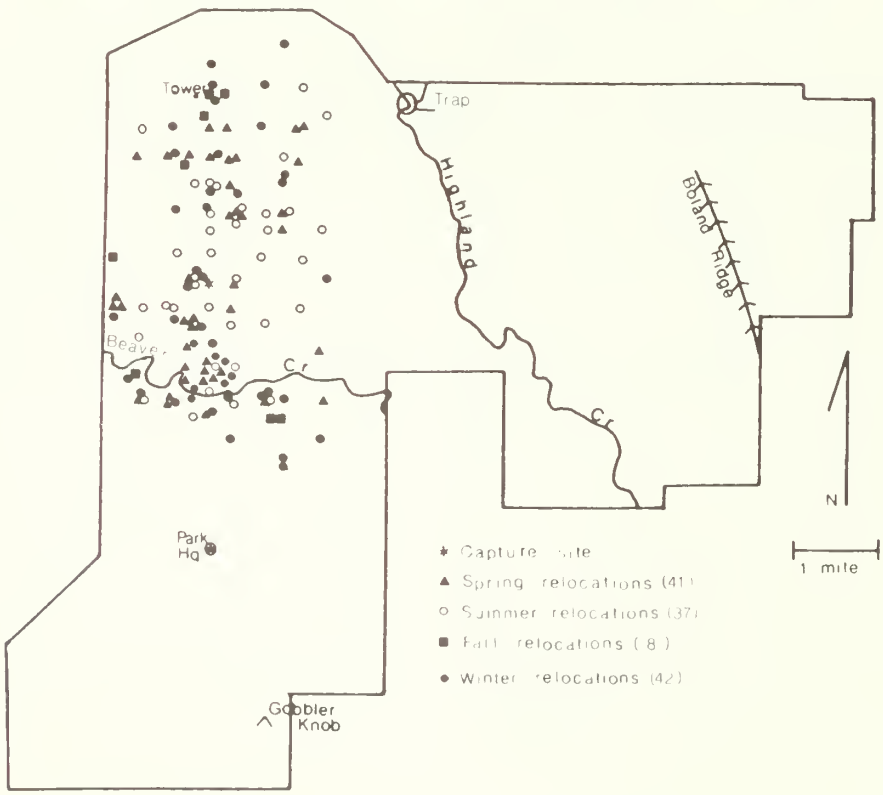

Figure 15. Locations of elk BC2 from 26 November 1973 to 10 January 1975.

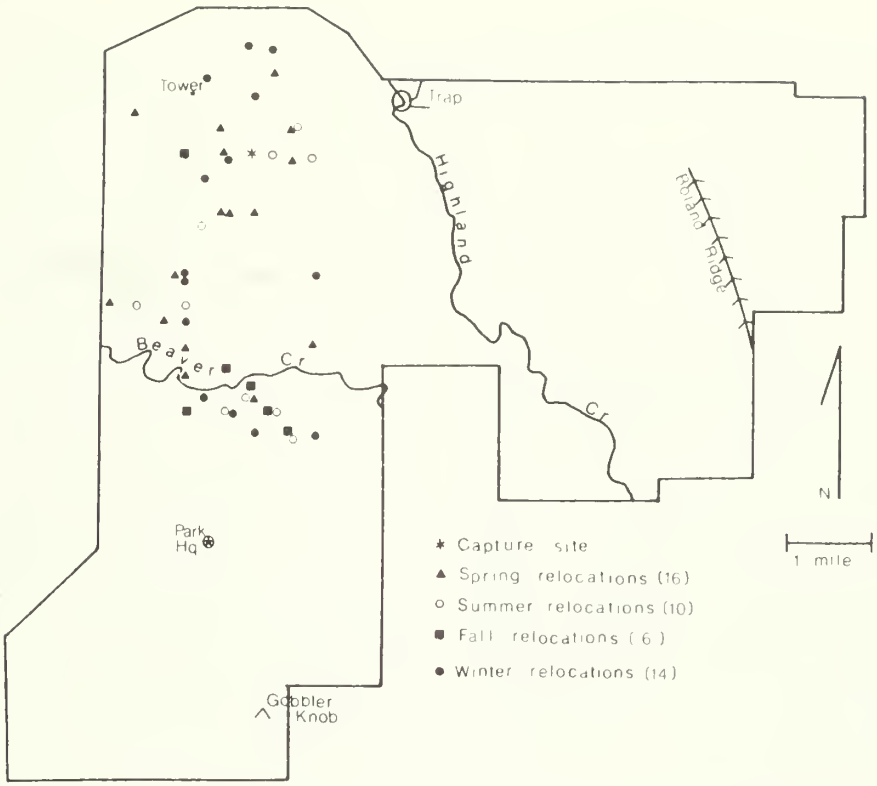

Figure 16. Locations of elk BC3 from 18 January 1974 to 7 March 1975.

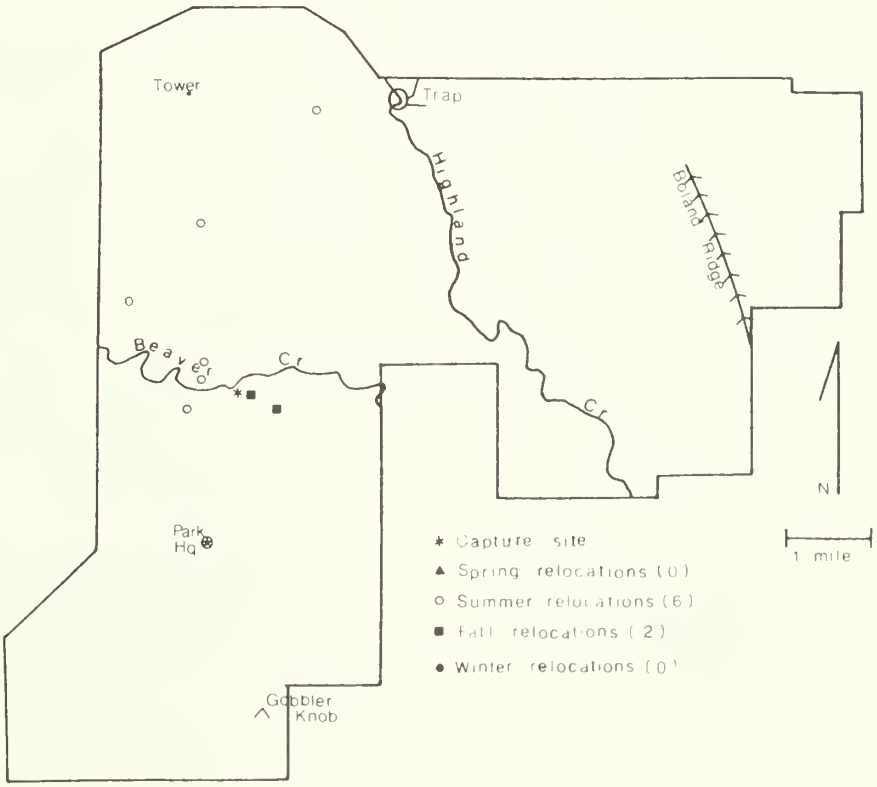

Figure 17. Locations of elk BC4 from 31 May to 26 September 1974.

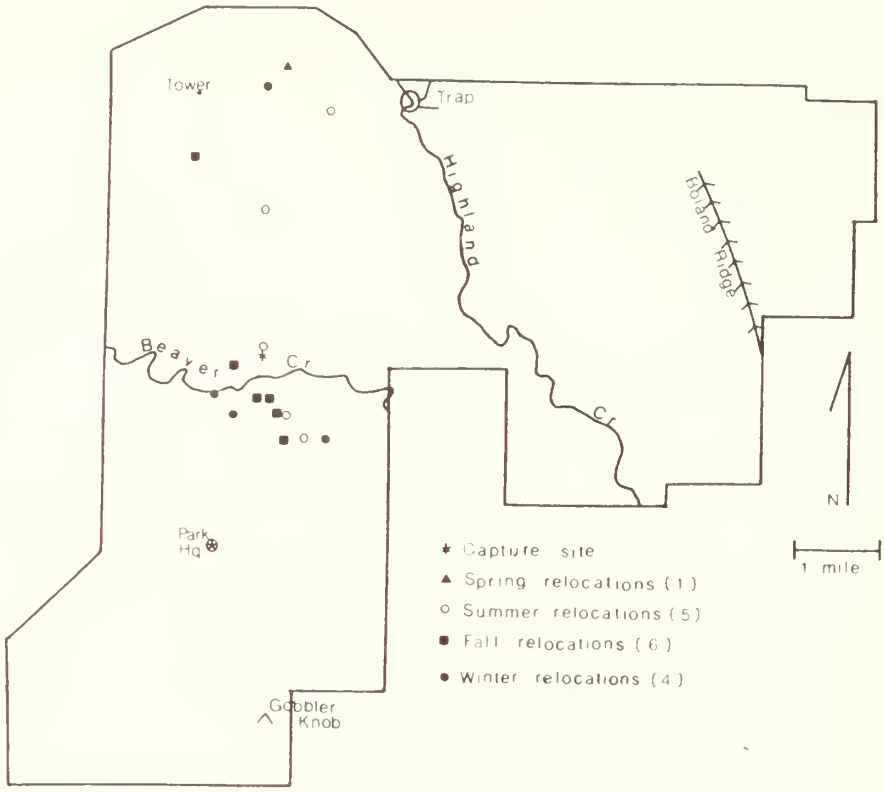

Figure 18. Locations of elk BC5 from 5 June 1974 to 5 October 1975.

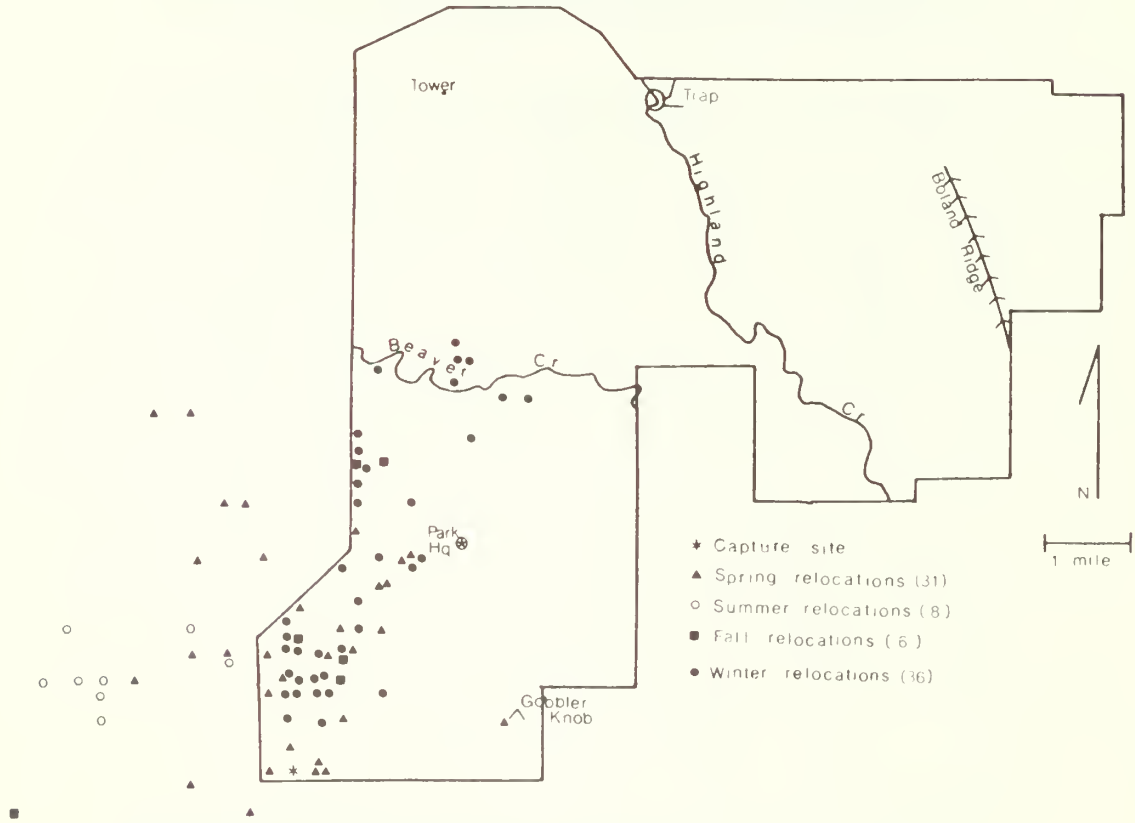

Figure 19. Locations of elk GK1 from 4 January 1974 to 4 October 1975.

park, was relocated 81 times (Fig. 19). She moved to an area just south of Beaver Creek on 9 January and was seen associated with elk marked in the Beaver Creek region. She again was relocated in association with Beaver Creek elk north of Beaver Creek on 10 and 11 January. This elk was not relocated again until 16 January, when she was in the Gobbler Knob region. She remained in the Gobbler Knob region until the morning of 6 February, when she was seen just south of Beaver Creek with GK2 and BC2. On the evening of 6 February, and on both the morning and evening of 7 February, she remained close to Beaver Creek and was seen associated with elk GK2, BC1, and BC2. On 8 February, she left the Beaver Creek elk and was relocated in a wooded area about a mile northwest of park headquarters. She returned to the southwestern corner of the park on 13 February and remained in this area until 4 April (except for a brief period spent near Gobbler Knob in early March). On this date, this elk and elk GK2 were seen as part of a group of 12 just west of the park boundary fence in the Black Hills National Forest. Elk GK1 remained in the national forest until 2 October 1974, when she returned to the park (except for 2 days in later April when she was seen inside the park). Elk GK1 and GK2 were seen with groups of elk ranging in size from 5 to 16 animals while in the national forest. Elk GK1 remained in the Gobbler Knob region throughout the winter of 1974–75, except for one relocation made in the Beaver Creek region just south of Beaver Creek near the park's western boundary on 9 December 1974. She was not associated with Beaver Creek elk at this time. This elk was not seen during the summer of 1975 but was last seen on 4 October 1975 in the Gobbler Knob region. Her radio stopped functioning sometime after 29 July 1974.

Elk GK2, the adult cow marked on 18 January 1974 near Wind Cave Canyon, was relocated 54 times (Fig. 20). On 20 January 1974, just 2 days after being marked, she was seen with elk BC1 and BC2 about 1.25 miles southeast of the fire tower, in the Beaver Creek region. She remained in the Beaver Creek region, and associated with Beaver Creek elk, until sometime between 7 and 12 February 1974. On one occasion she was relocated as far north as 0.4 km (0.25 mile) north of the fire tower. On 13 February, she was seen again in the Gobbler Knob region, and remained there until 4 April 1974, when she was seen with elk GK1 and 10 others, outside the park in the Black Hills National Forest. Elk GK2 was relocated only in the national forest until 19 August 1974, the date she was last located.

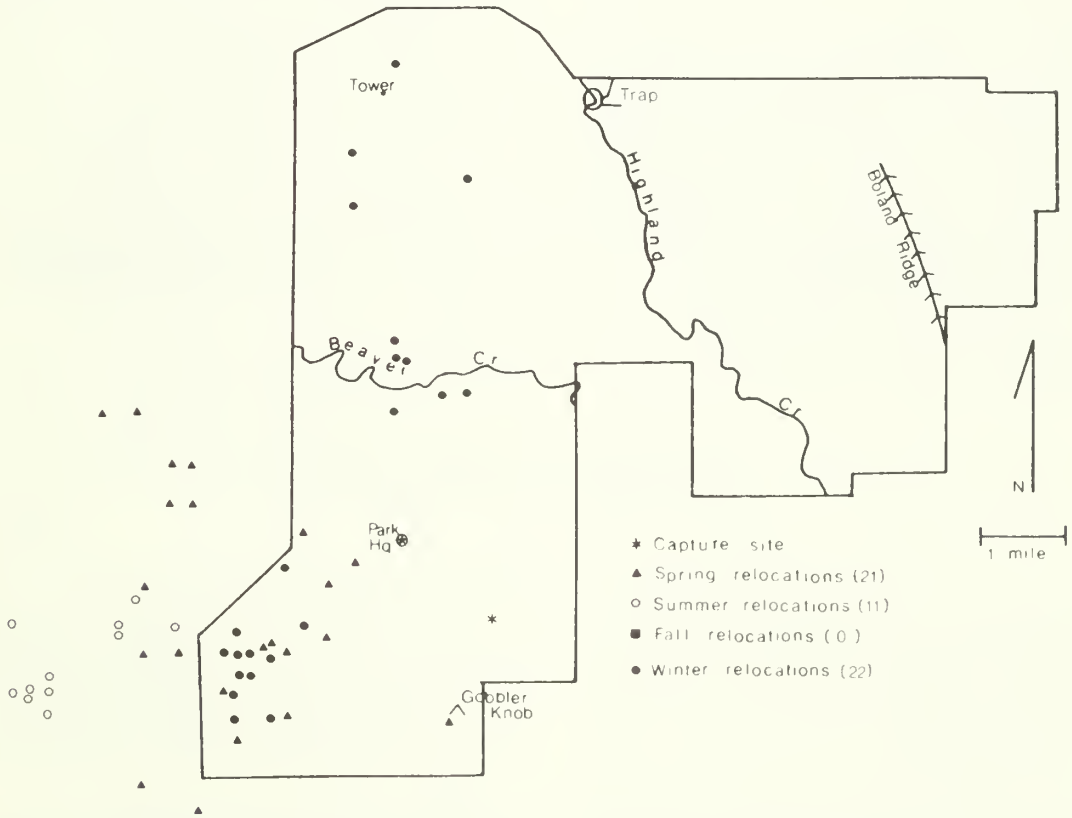

Figure 20. Locations of elk GK2 from 18 January to 19 August 1974.

Group Constancy

The degree of association between any two individuals was expressed by using the following formula for the coefficient of association:

$$\frac{2ab}{A+B}$$

where A is the number of times elk A was observed throughout a particular period of time, B is the number of times elk B was observed throughout the period, and ab is the number of times that A and B were seen together throughout the period. Theoretically, the coefficient of association would be 0 if two individuals are never seen together and 1 if they are always observed together. Since elk were marked at different times throughout the study, coefficients of association for any set of two individuals were calculated where both elk were known to be marked for the same period of time. Thus, the periods of time used for which coefficients of association were computed varied between sets of individuals. Knight (1970), who used this method to determine elk group constancy in the Sun River herd of Montana, found that mean coefficients of association were relatively low. He reported that groups of elk seldom contained the same individuals all the time. He interpreted a coefficient of association lower than 0.5 as meaning that the attraction or association between particular elk within the population was not great.

In this study, coefficients of association between individuals within a region were relatively high compared with the degree of association between individuals of different regions (Table 3). The degree of association for elk marked in the Boland Ridge region varied from 0.42 to 0.68 ($\bar{x} = 0.53$). The highest degree of association occurred between elk BR1 and BR3. Both of these elk had a somewhat lower association index with elk BR2. Elk from this region were never seen associated with elk marked in any other regions of the park.

Table 3. Coefficients of association for marked members of cow–calf herds in Wind Cave National Park.

	GK1	GK2	BC1	BC2	BC3	BC4	BC5	BR1	BR2	BR3
GK1		0.63	0.04	0.05	0	0	0	0	0	0
GK2			0.12	0.15	0	0	0	0	0	0
BC1				0.44	0.43	0.24	0.29	0	0	0
BC2					0.38	0.38	0.33	0	0	0
BC3						0.12	0.54	0	0	0
BC4							0.08	0	0	0
BC5								0	0	0
BR1									0.42	0.68
BR2										0.49

Elk marked in the Beaver Creek region had coefficients of association ranging from 0.08 to 0.54 ($\bar{x} = 0.32$). Except for BC3 and BC5, there seemed to be no great attraction between marked individuals in this region. However, marked elk were never seen outside the region, and individuals commonly were seen associated in different combinations. Elk of this region, as well as other regions, occurred in several groups that changed in composition as they intermingled and individuals left one group and joined another for varying periods. Associations between Beaver Creek and Gobbler Knob elk were relatively low, ranging from 0.04 to 0.15 ($\bar{x} = 0.09$) for those pairs where associations occurred. Coefficients of association may have been even lower had we not observed intensively the movements of the Gobbler Knob elk while they were in the Beaver Creek region.

The coefficient of association for Gobbler Knob elk GK1 and GK2 was relatively high (0.63).

Bull groups changed in composition often, and no lasting associations were detected between particular marked individuals. Coefficients of association for marked bulls were relatively low, ranging from 0.04 to 0.28 ($\bar{x} = 0.12$), for those pairs where associations occurred.

AREAS OF INTENSIVE USE

The areas used most intensively by all elk in any particular region of the park were closely similar to the areas used by individuals marked in that region. Cow–calf groups in the Boland Ridge region used areas on or east of Boland Ridge intensively during all seasons, and the area west of Red Valley adjacent to Highland Creek most intensively during summer and less intensively during other seasons (Fig. 21 and 22).

Ranges used by cow–calf groups in the Beaver Creek region were similar for all seasons, with somewhat lower usage of the forested area between Beaver Creek and Sanctuary prairie dog town during fall and winter and the area south of Beaver Creek during spring and summer.

Ranges used by cow–calf groups of the Gobbler Knob region were similar during spring and fall.

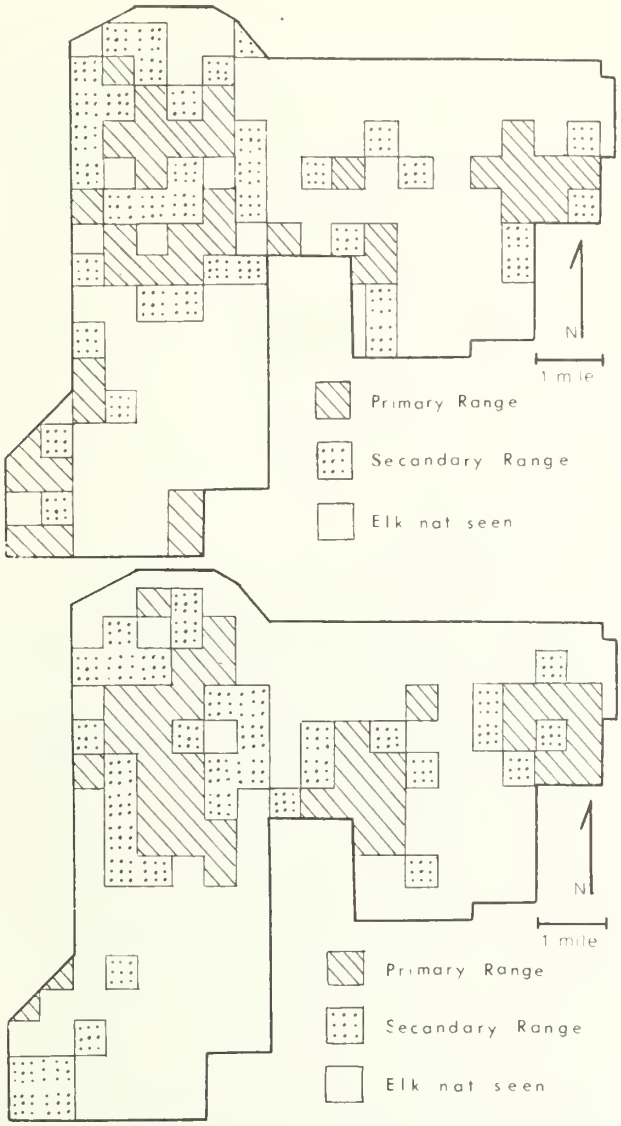

Figure 21. Primary and secondary ranges used by cow–calf groups during spring 1974 (*top*), and summer 1973 and 1974 (*bottom*).

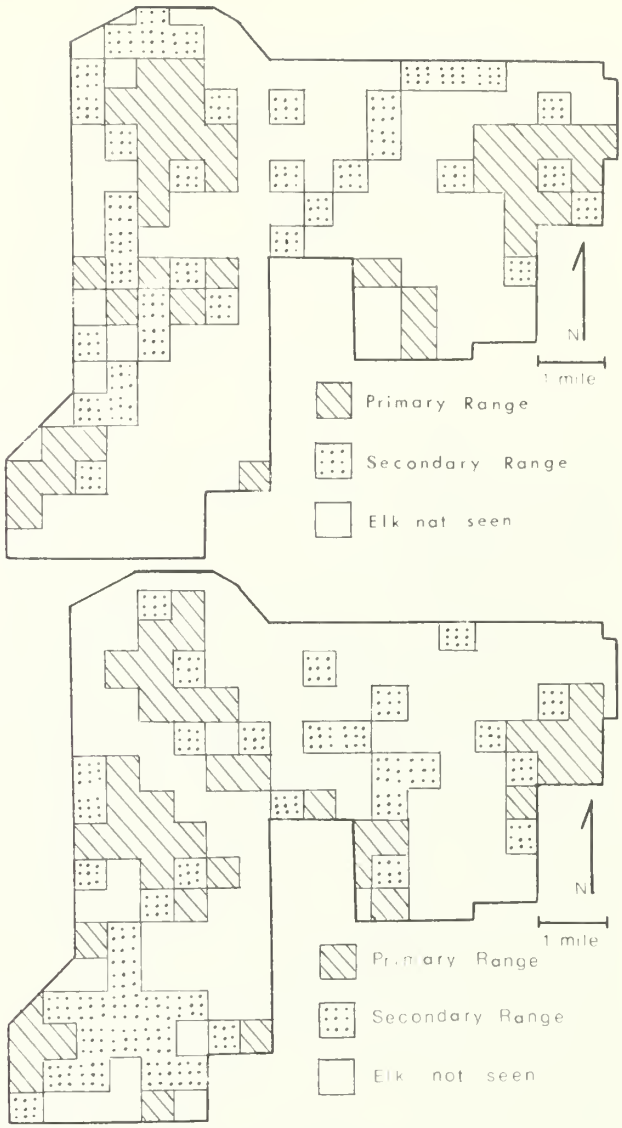

Figure 22. Primary and secondary ranges used by cow–calf groups during fall 1973 and 1974 (*top*), and winter 1973–74 and 1974–75 (*bottom*).

Groups in this region used the park's extreme southwestern corner most intensively, although use of this region was less during summer, probably because elk moved to areas west of the park (Figs. 19 and 20). Areas in or near Bison Flats and Gobbler Knob were used more intensively during winter than during the rest of the year.

Bulls generally used the northern half of the park much more intensively than the southern half during all seasons (Figs. 23 and 24), and made little use of the park's southwestern portion during winter and spring. The area east of Red Valley was used less intensively during spring than during the rest of the year. Ranges west of Rankin Ridge were used less during spring and winter than during summer and fall. Bulls used areas in and near Sanctuary prairie dog town (Fig. 3) and just south of Beaver Creek most intensively during fall, and less intensively during spring.

Factors Influencing Areas Used

Elk were seen most often during several hours after sunrise and before sunset (Fig. 25). Few elk were seen during midday.

Craighead et al. (1973) found that most of an elk's daily activities in Yellowstone National Park comprise either feeding (44%) or bedding (46%). During this study, most elk were seen feeding at sunrise, and few were bedded (Fig. 26). As the morning progressed, feeding declined and bedding increased. The percentage of elk seen feeding generally increased again in midafternoon and reached a second daily peak at sunset. Elk used grassland most intensively during hours closest to sunrise and sunset, and least at midday. Forest areas were used more during hours closest to midday (Fig. 27). Feeding activity generally occurred in grassland areas; 91% of all feeding elk were in grassland and 9% were in forest. In some studies, elk have

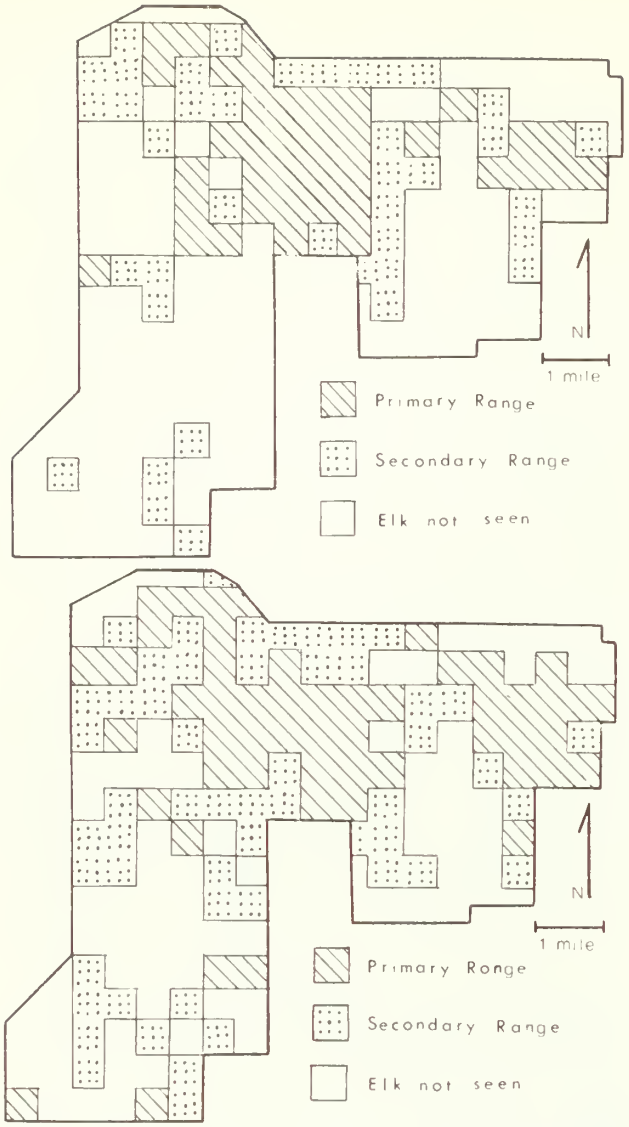

Figure 23. Primary and secondary ranges used by adult bulls during spring 1974 (*top*), and summer 1973 and 1974 (*bottom*).

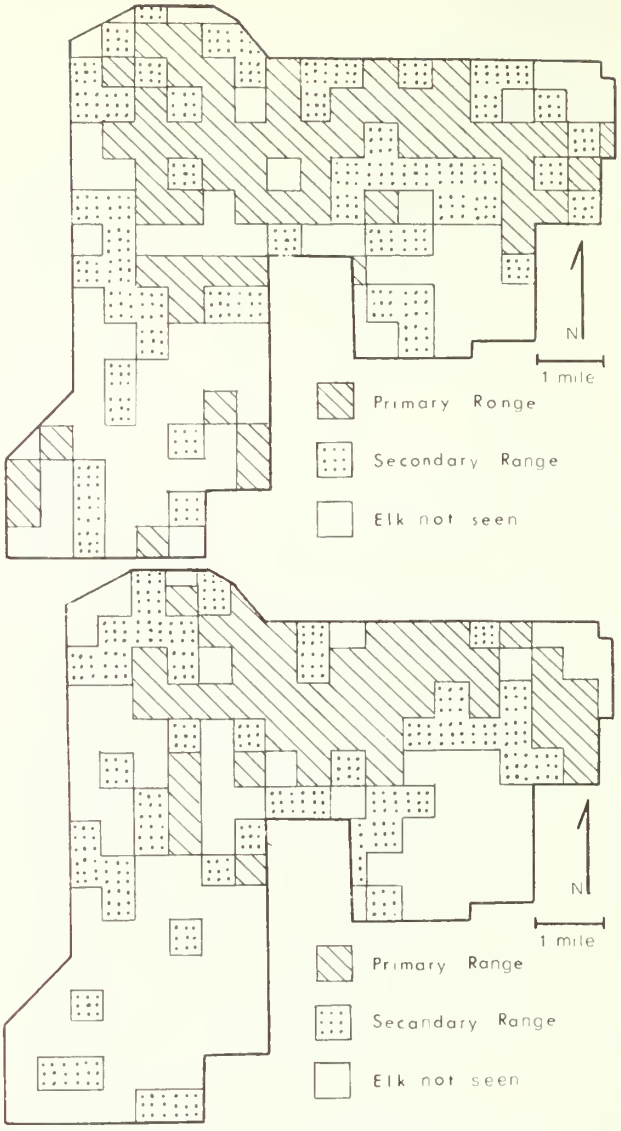

Figure 24. Primary and secondary ranges used by adult bulls during fall 1973 and 1974 (*top*), and winter 1973–74 and 1974–75 (*bottom*).

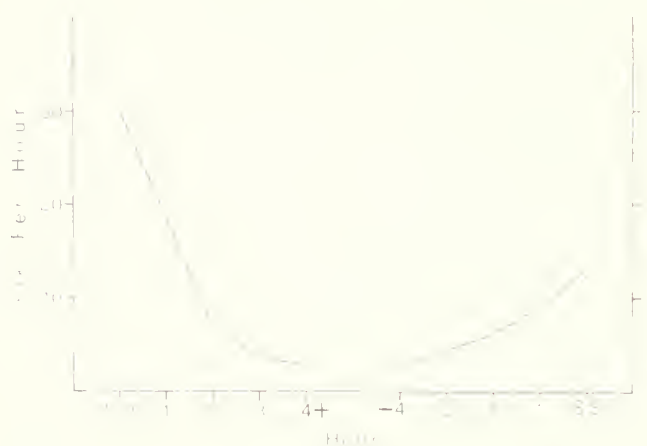

Figure 25. Numbers of elk seen per hour for each of the 4 hours after sunrise (SR) and before sunset (SS) at Wind Cave National Park.

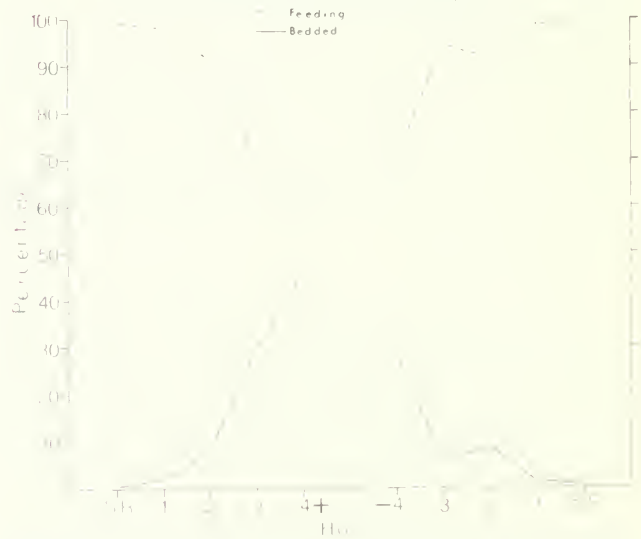

Figure 26. Percentages of all elk seen feeding or bedded during early morning and late afternoon hours at Wind Cave National Park.

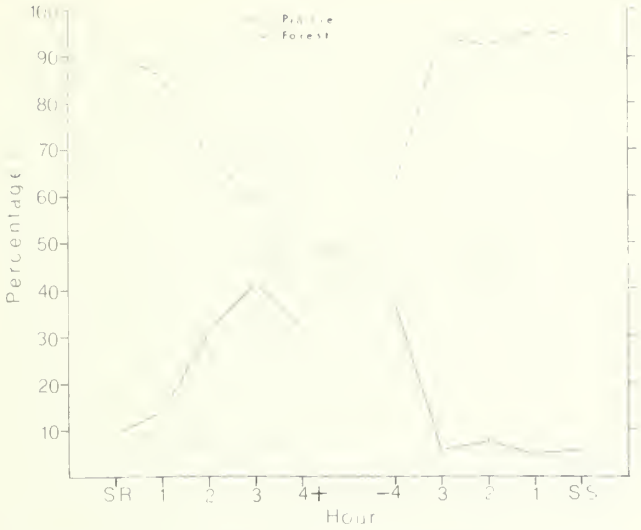

Figure 27. Percentages of all elk seen in either forest or grassland during early morning and late afternoon hours at Wind Cave National Park.

been found to prefer grasses (Baldwin and Patton 1938; DeNio 1938; Gaffney 1941; Harper 1962; Morris and Schwartz 1957). In contrast to feeding elk, 60% of the bedded elk were seen in forest and 40% in grassland. Elk of the Boland Ridge region seemed to bed in grassland areas more than did elk of the other two regions, perhaps because these elk usually were not near public roads and thus were seldom disturbed by park visitors.

More elk were seen in grassland areas than in forest (Table 4), probably because elk were seen more easily in grassland and also because grassland constituted a larger proportion of the park, and thus more time was spent observing in this type of habitat. Use of grassland areas differed only slightly during the four seasons, but use of grassland was above average during spring and fall. Grassland areas where prairie dog towns occurred generally received highest use during fall and little use during winter. Percentages of all elk (2,395) seen on prairie dog towns during the four seasons were as follows: spring, 20.2; summer, 32.1; fall, 43.0; and winter, 4.7. Whether this was because elk used prairie dog towns or because prairie dogs occupied prime, level, grassland areas, often near forest, is unknown. Elk used prairie dog towns extensively as rutting areas, which explains some of the heavy fall use.

Table 4. Percentages of all elk seen in either forest or grassland during the four seasons at Wind Cave National Park.

Season	No.	Forest	Grassland
Spring	4,235	8.9	91.1
Summer	5,477	15.4	84.6
Fall	6,171	11.1	88.9
Winter	8,029	16.1	83.9
Total or averages	23,912	12.9	87.1

Elk preferred to use areas of level ground (Tables 5 and 6) and gentle slopes (0–25°) during all seasons, but used steeper slopes more during fall and winter than during other seasons (Table 5). The preferences of elk for different exposures were ranked as follows (from highest to lowest): east, south, west, and north (Table 6). Winter was the only season in which use of all exposures was nearly equal. Use of eastern exposures declined in summer. Elk used southern exposures uniformly during all seasons. Western exposures were used relatively more during fall and winter and northern exposures during winter. Snow depth was seldom, if ever, great enough to influence feeding. Mackie (1970) found that (1) use of northerly exposures by elk in the breaks of the Missouri River, Montana, was especially intensive during summer and winter; (2) western exposures received greater use in winter; (3) cold wind and deep snow, that prevailed in winter, did not seem to inhibit the use of northerly exposures; (4) slopes facing south, southeast, and east received relatively high use during spring; and (5) southern and southwestern exposures were used intensively in fall.

Table 5. Percentages of all elk seen on slopes of varying degrees of steepness during the four seasons at Wind Cave National Park.

		Degrees of slope	
Season	No.	0–25°	>25°
Spring	4,208	72.4	27.6
Summer	5,462	73.3	26.7
Fall	6,112	69.0	31.0
Winter	7,934	63.8	36.2
Total or averages	23,716	69.6	30.4

Table 6. Percentages of all elk seen on level ground or slopes with various exposures during the four seasons at Wind Cave National Park.

Season	No.	Level	Exposure			
			N	S	E	W
Spring	4,224	38.3	6.5	18.7	23.4	13.1
Summer	5,470	39.7	11.9	19.2	15.6	13.6
Fall	6,125	25.3	9.4	19.1	27.4	18.8
Winter	8,439	25.0	19.0	19.1	19.3	17.6
Total or averages	24,258	32.1	11.7	19.0	21.4	15.8

DISCUSSION AND MANAGEMENT IMPLICATIONS

Wind Cave National Park was occupied by three relatively discrete cow–calf herds and, in all probability, also by relatively discrete bull herds. Other researchers have reported the presence of multiple herds in small, specified areas but none as small as WCNP (114 km^2 or 44 square miles). McCullough (1971) found that Tule elk in Owens Valley, California (1,942 km^2 or 750 square miles) occurred in five relatively discrete herds, and Troyer (1960) noted that Roosevelt elk introduced to Afognak Island, Alaska (2,020 km^2 or 780 square miles) were also divided into five major herds. Both researchers found little interchange of individuals between herds.

Group composition at WCNP changed through time. Others have found that group composition is dynamic and that elk do not necessarily remain in well-defined groups indefinitely (Craighead et al. 1973; Harper 1964, 1966; Knight 1970; Mackie 1970; Moran 1973; Struhsaker 1967). Franklin et al. (1975) found composition of a group of nonmigratory Roosevelt elk to be constant, even when the group temporarily became associated with other groups. They speculated that this behavior is related to group development; large groups evolve stronger social ties and are more stable than smaller, less strongly developed groups.

Researchers studying elk migration patterns in or near Yellowstone National Park have shown that elk herds generally occupied traditional winter and summer ranges and that only a few individuals moved between herds (Brazda 1953; Cole 1969; Craighead et al. 1972; Houston 1974; Murie 1951). Schwartz and Mitchell (1945) reported that both resident and migratory Roosevelt elk in Washington used traditional wintering areas, and Knight (1970) reported use of traditional winter ranges by elk from the Sun River herd in Montana.

Areas used by cows and calves of the Beaver Creek region have shifted during recent years. Before helicopter trapping operations were begun in 1970, cows and calves frequently were seen in the vicinity of the corral. During 1969 and 1970, 80 elk inadvertently wandered into the trap and were captured. During the present study, however, cow–calf groups were seldom seen within a mile of the structure. This change in movements may have been a natural shift because the group of cows and calves that occupied the area near the trap were captured and shipped out, or the cows may have learned to fear the trap.

Before this study, WCNP's elk population was censused periodically and reduced to prevent overuse of the range. Elk from the Boland Ridge region were caught most easily during helicopter drives because trap wings open to the east, toward that region (Fig. 1). Elk west and south of the trap were more difficult to capture because they had to be driven long distances through rough, forested terrain, around the wings, and back west into the trap. Nevertheless, many elk from the Beaver Creek region were trapped (Lovaas 1973a). Elk have never been driven successfully to the trap from the Gobbler Knob region.

The total elk population in March 1975 was estimated to be 450–500 animals (Lovaas 1975), based on both aerial and ground counts. Although no census was made in the winter of 1975–76, elk numbers during this time were reportedly higher than during the previous winter, and the Beaver Creek cow–calf herd exceeded 200 animals. To attain the population size recommended in the park's wildlife management plan

(150–300), the population had to be reduced.

Information from this study, indicating the presence of three separate cow–calf herds in the park, was used in elk trapping operations during January 1976 and 1977. In 1976, a herd reduction of up to 210 cows and calves was planned, with the helicopter costs to be paid by several Indian tribes who were to receive the elk. In a memorandum of understanding between the National Park Service and the tribes, a quota of 50 cows and calves was established for the Boland Ridge herd and 160 for the Beaver Creek herd. If more than the quota were captured from either herd, excess animals were to be released to prevent overreduction of that herd. All bulls captured also would be removed from the park and would not count against the quotas. Twenty-two elk were captured from the Boland Ridge region and 108 from the Beaver Creek region. Two elk died during the trapping operation, and the remaining 128 were divided among four Indian tribes and were shipped to their reservations by truck.

In 1977, the same agreement was used with five Indian tribes, except that the quotas were 70 cows and calves from the Boland Ridge herd and 230 from the Beaver Creek herd. One hundred and fifty-four cows and calves were trapped from the Beaver Creek region and 41 from the Boland Ridge region. Only 185 were shipped; 3 died, 1 reacted positively to brucellosis, and 6 were released.

Little effort was spent in trying to trap adult bulls because they had proved to be difficult to capture in previous helicopter drives (Lovaas 1973b). Those occurring with cow–calf groups were often captured.

Elk numbers in the Gobbler Knob region declined in recent years. The total herd count was 74 in 1970 (Lovaas 1970), but only 46 in 1974 and 41 in 1975. Hunting pressure in the area just west of the park evidently increased, as determined by an examination of hunter report cards sent to the South Dakota Department of Game, Fish, and Parks from 1971 to 1974. Several elk were killed within 6.4 km (4 miles) of the park's western boundary during the September hunting seasons of 1971 through 1974 (Table 7). Because at least a portion of the Gobbler Knob herd remains in the area during the hunting season (e.g., elk GK1), some of the Gobbler Knob elk were probably taken by hunters. Poaching was also a factor. Because this herd was declining, no reductions were contemplated for that region. Periodic censusing will be used to determine if future reduction will be required.

According to National Park Service policy (U.S. Department of the Interior 1975), regulation of wildlife populations by natural means is preferred. However, when natural means are not feasible, live trapping is the preferred method of direct management, and public hunting outside the boundary of the park is encouraged.

Natural control of elk numbers in WCNP is not feasible because numbers and kinds of predators found in this relatively small, fenced park are insufficient to regulate the elk population. However, movements of elk into the Black Hills National Forest, a public hunting area adjacent to the Gobbler Knob region, is encouraged by the presence of the 122-cm (4-ft) fence in the park's southwest corner. Low fences along other boundaries of the park are not practical because elk could invade private lands. According to National Park Service policy, therefore, the elk population at WCNP is being regulated by those means considered most desirable—hunting outside the boundary and trapping and transplanting. If an additional trap is needed for future management of the Gobbler Knob and Beaver Creek elk, it could be built between the Beaver Creek and Gobbler Knob regions. Wind Cave Canyon (Fig. 1) would provide a site hidden from public view but near a road that would allow easy removal of elk by truck. It is close to areas used by elk in winter. Other possible trap sites are east of Lookout Point on the south side of Beaver Creek and the grassland area in and adjacent to Sanctuary prairie dog town. This last-named location may be undesirable, however, because of its close proximity to woods, which may be detrimental to effective elk trapping, and its poor location in relation to Gobbler Knob elk. Experimental drives should be conducted before trap construction to make sure that elk can be driven to any new trap site.

Table 7. Number of elk reported killed during the September hunting seasons of 1971 through 1974 within 6.4 km (4 miles) of the western boundary of Wind Cave National Park and for the remainder of the southern Black Hills region.

Year	No. of reported kills near the park				Additional kills reported for the entire southern Black Hills region
	Bulls	Cows	Calves	Total	
1971	5	2	0	7	34
1972	4	2	0	6	53
1973	7	7	4	18	32
1974	8	5	0	13	33

Bulls could be reduced by baiting them into a trap, as we did during this study. Additional traps would be needed to capture bulls from the Boland Ridge and Gobbler Knob regions. Dalke et al. (1965) showed that elk use salt most readily during May and June. We found that bulls also were captured during late fall and winter by using salt as bait.

Range studies are needed in each of the three regions of the park to determine more adequately optimum herd size for each region. A better understanding of the relationship of elk to other herbivores in the park also is needed.

REFERENCES

Baldwin, W. P., and C. P. Patton. 1938. A preliminary study of the food habits of elk in Virginia. *Trans. N. Am. Wildl. Conf.* **3**:747–755.

Beetle, A. A. 1970. Recommended plant names. Univ. Wyo. Agric. Exp. Stn. Res. J. 31. 124 p.

Brazda, A. R. 1953. Elk migration patterns and some of the factors affecting movements in the Gallatin River Drainage, Montana. *J. Wildl. Manage.* **17**(1):9–23.

Cole, G. F. 1969. The elk of Grand Teton and southern Yellowstone National Parks. Research Rep. GRTE–N–1. Yellowstone National Park. 192 p.

Craighead, J. J., M. G. Hornocker, M. W. Shoesmith, and R. I. Ellis. 1969. A marking technique for elk. *J. Wildl. Manage.* **33**(4):906–909.

Craighead, J. J., G. Atwell, and B. W. O'Gara. 1972. Elk migrations in and near Yellowstone National Park. *Wildl. Monogr.* 29. 48 p.

Craighead, J. J., F. C. Craighead, Jr., R. L. Ruff, and B. W. O'Gara. 1973. Home ranges and activity patterns of nonmigratory elk of the Madison Drainage herd as determined by biotelemetry. *Wildl. Monogr.* 33. 50 p.

Dalke, P. D., R. P. Beeman, F. J. Kindel, R. J. Robel, and T. R. Williams. 1965. Use of salt by elk in Idaho. *J. Wildl. Manage.* **29**(2):319–332.

DeNio, R. M. 1938. Elk and deer foods and feeding habits. *Trans. N. Am. Wildl. Conf.* **3**:421–427.

Dusek, G. L. 1975. Range relations of mule deer and cattle in prairie habitat. *J. Wildl. Manage.* **39**(3):605–616.

Franklin, W. L., A. S. Mossman, and M. Dole. 1975. Social organization and home range of Roosevelt elk. *J. Mammal.* **56**(1):102–118.

Gaffney, W. S. 1941. The effects of winter elk browsing, south fork of the Flathead River, Montana. *J. Wildl. Manage.* **5**(4):427–453.

Harper, J. A. 1962. Daytime feeding habits of Roosevelt elk on Boyes Prairie, California. *J. Wildl. Manage.* **26**(1):97–100.

———. 1964. Movement and associated behavior of Roosevelt elk in southwestern Oregon. *Proc. Annu. Conf. Western Assoc. State Game and Fish Comm.*, San Francisco, Calif. **44**:139–141.

———. 1966. Ecological study of Roosevelt elk. Game Res. Rep. No. 1. Res. Div., Oregon State Game Comm. 29 p.

Heezen, K. L., and J. R. Tester. 1967. Evaluation of radiotracking by triangulation with special reference to deer movements. *J. Wildl. Manage.* **31**(1):124–141.

Hipschman, D. 1959. A look at the past half century. *S. D. Conserv. Digest* **26**(2):20–31, 37.

Houston, D. B. 1974. The northern Yellowstone elk, parts I and II—history and demography. Yellowstone National Park. 185 p.

Johnson, D. E. 1951. Biology of the elk calf, *Cervus canadensis nelsoni*. *J. Wildl. Manage.* **15**(4):396–410.

Knight, R. R. 1966. Effectiveness of neckbands for marking elk. *J. Wildl. Manage.* **30**(4):845–846.

———. 1970. The Sun River elk herd. *Wildl. Monogr.* 23. 66 p.

Lovaas, A. L. 1970. Typewritten memorandum of 13 March 1970 to Superintendent of Wind Cave National Park, reporting on aerial elk census.

———. 1973a. A cooperative elk trapping program in Wind Cave National Park. *Wildl. Soc. Bull.* **1**(2):93–100.

———. 1973b. Prairie dogs and black-footed ferrets in the national parks. Pages 139–148 *in* R. L. Linder and C. N. Hillman. eds. Black-Footed Ferret and Prairie Dog Workshop. South Dakota State Univ., Brookings.

———. 1975. Typewritten memorandum of 19 March 1975 to Superintendent of Wind Cave National Park, reporting on aerial elk census.

Lovaas, A. L., and P. T. Bromley. 1972. Preliminary studies of pronghorn antelope—blacktail prairie dog relations in Wind Cave National Park. Pages 115–156 *in* Proc. 5th Bienn. Antelope States Workshop, Billings, Mont.

Lovaas, A. L., J. L. Egan, and R. R. Knight. 1966. Aerial counting of two Montana elk herds. *J. Wildl. Manage.* **30**(2):364–369.

Mackie, R. J. 1970. Range ecology and relations of mule deer, elk, and cattle in the Missouri River Breaks, Montana. *Wildl. Monogr.* 20. 79 p.

McCullough, D. R. 1971. The Tule Elk, Its History, Behavior, and Ecology. Univ. of Calif. Press, Berkeley. 209 p.

Moran, R. J. 1973. The Rocky Mountain Elk in Michigan. Michigan Dept. of Nat. Resour. R and D Dep. No. 267. 93 p.

Morris, M. S., and J. E. Schwartz. 1957. Mule deer and elk food habits on the National Bison Range. *J. Wildl. Manage.* **21**(2):189–193.

Murie, O. J. 1951. The Elk of North America. The Stackpole Co., Harrisburg, Pa. 376 p.

Petersburg, S. J. 1973. Bull bison behavior at Wind Cave National Park. M.S. Thesis. Iowa State Univ., Ames. 302 p.

Progulske, D. R. 1957. A collar for identification of big game. *J. Wildl. Manage.* **21**(2):251–252.

Russo, J. P. 1964. The Kaibab North Deer Herd, Its History, Problems and Management. Ariz. Game Fish Dep. Wildl. Bull. 7. 195 p.

Schwartz, J. E., and G. F. Mitchell. 1945. The Roosevelt elk on the Olympic Peninsula, Washington. *J. Wildl. Manage.* **9**(4):295–319.

Shult, M. J. 1972. American bison behavior patterns at Wind Cave National Park. Ph.D. Thesis. Iowa State Univ., Ames. 178 p.

Smuts, G. L. 1974. Game movements in the Kruger National Park and their relationship to the segregation of sub-populations and the allocation of culling compartments. *J. S. Afr. Wildl. Manage. Assoc.* **4**(1):51–58.

Struhsaker, T. T. 1967. Behaviour of elk (*Cervus canadensis*) during the rut. *Z. Tierpsychol.* **24**:80–114.

TROYER, W. A. 1960. The Roosevelt elk on Afognak Island, Alaska. *J. Wildl. Manage.* **24**(1):15–21.

U.S. DEPARTMENT OF THE INTERIOR. 1975. Management Policies, National Park Service. 125 p.

U. S. SOIL CONSERVATION SERVICE. 1969. Conservation plan for Wind Cave National Park. 46 p.

VARLAND, K. L. 1976a. Herd organization and movements of elk in Wind Cave National Park, South Dakota. M.S. Thesis, Iowa State Univ., Ames. 153 p.

———. 1976b. Techniques for elk immobilization with succinylcholine chloride. *Proc. Iowa Acad. Sci.* **82**(3–4) 194–197.

ACKNOWLEDGMENTS

The cooperation of many people made this project possible, and we wish to express our appreciation to the following:

Drs. Arnold O. Haugen, Leader, and Kenneth R. Russell, Assistant Leader, Iowa Cooperative Wildlife Research Unit, who helped to initiate the project and provided expertise at the beginning stages of work; the staff at Wind Cave National Park (special thanks to Lester McClanahan, Superintendent, and seasonal rangers Thomas Bean, Douglas Buehler, and Larry Frederick, for their assistance); Jerry D. Andrew, Iowa State University, for field and clerical assistance during the latter portion of the project; David Schlapkohl, Nancy Smith, Lorraine Martzahn, and Robert Major, Iowa State University, for their clerical help; John May and Drs. William K. Seitz, Michael K. Petersen, and David Graham, Iowa State University, who helped immobilize elk for marking; Dr. Richard Knight, National Park Service, for expert consultation before we began using a helicopter to pursue elk for immobilization and marking; Dr. David F. Cox, Iowa State University, for assisting with computer programming; Dr. Erwin E. Klaas, Iowa Cooperative Wildlife Research Unit, who provided helpful editorial comments; and Hazel Clausen, Iowa Cooperative Wildlife Research Unit, for typing the manuscript; personnel of the South Dakota Department of Game, Fish and Parks for providing ear tags and hunter report cards; and Carolyn Varland for her field and clerical assistance.

This project was funded by the National Park Service and the U.S. Fish and Wildlife Service and was administered by the Iowa Cooperative Wildlife Research Unit, supported jointly by the U.S. Fish and Wildlife Service, Iowa State University of Science and Technology, Iowa State Conservation Commission, and the Wildlife Management Institute. Journal Paper No. J-8912 of the Iowa Agriculture and Home Economics Experiment Station; Project No. 1998.

U.S. GOVERNMENT PRINTING OFFICE 1978—722-803